# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

*January 1955*

Kearny Generating Station of Public Service Electric & Gas Co.

**The Present Status of Steam Properties**

**Balancing Energy Needs Against Byproduct Fuel at Sparrows Point**

**Bare Tube Walls on Slag Tap Furnaces**

**Power Practices in 1954**

# COMBUSTION

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**Vol. 26** **No. 7**

## January 1955

## Feature Articles



## Editorials



## Departments



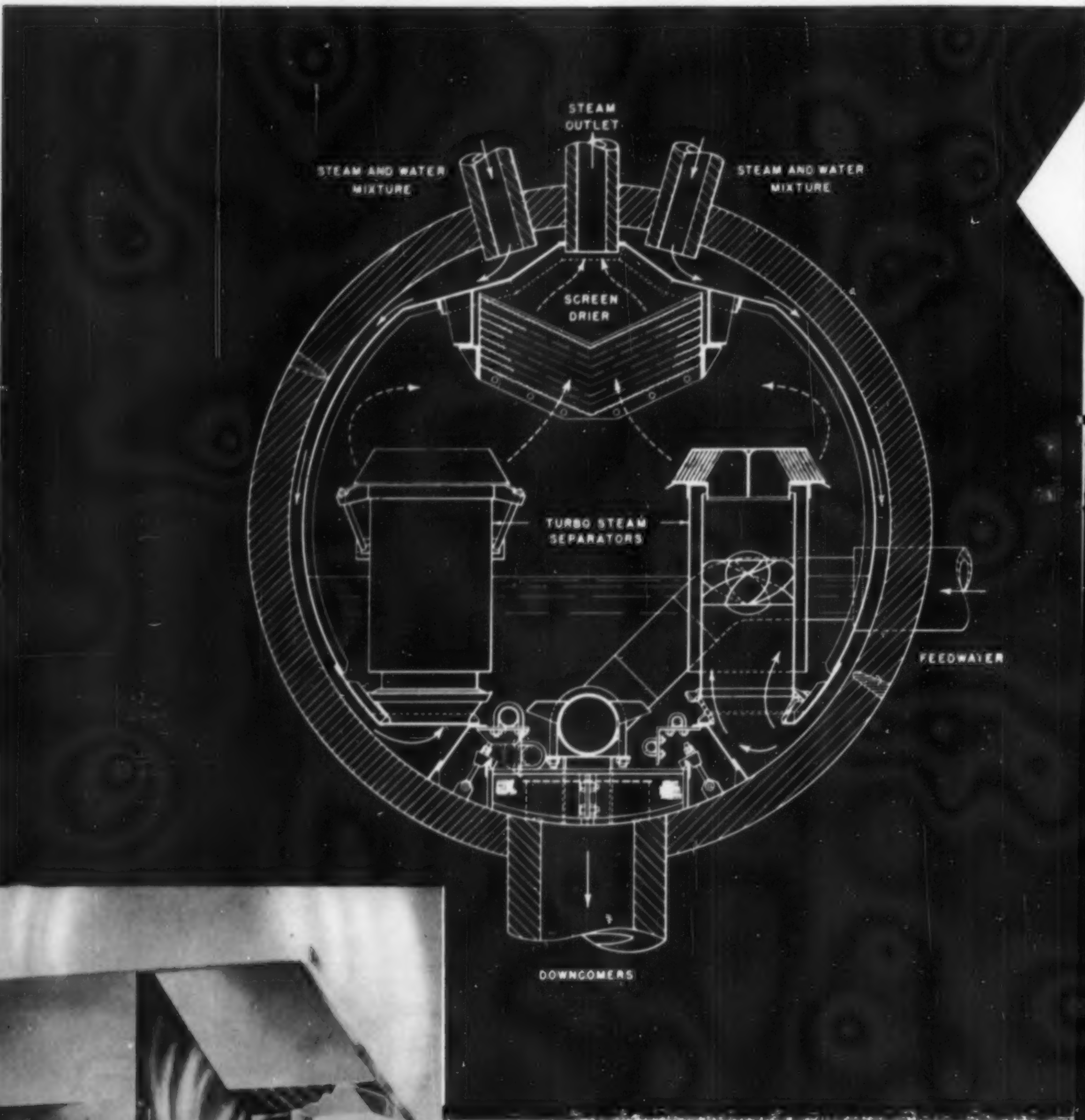
COMBUSTION published its annual index in the June issue and is indexed regularly by Engineering Index, Inc.



Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING, INC.
Joseph V. Santry, Pres.; Charles McDonough, Vice-Pres.; Otto Strauss, Treas.; Irving B. Swigart, Secy.
COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up and to consulting engineers in this field. To others the subscription rate, including postage, is $4 in the United States, $5.50 in Canada and Latin America and $7 in other countries. Single copies: Domestic, 40 cents; Foreign, 40 cents plus postage.  Publication Office, Easton, Pa. Issued the middle of the month of publication.
Acceptance under Section 34.64, P.L. & R., authorized by United States Post Office.

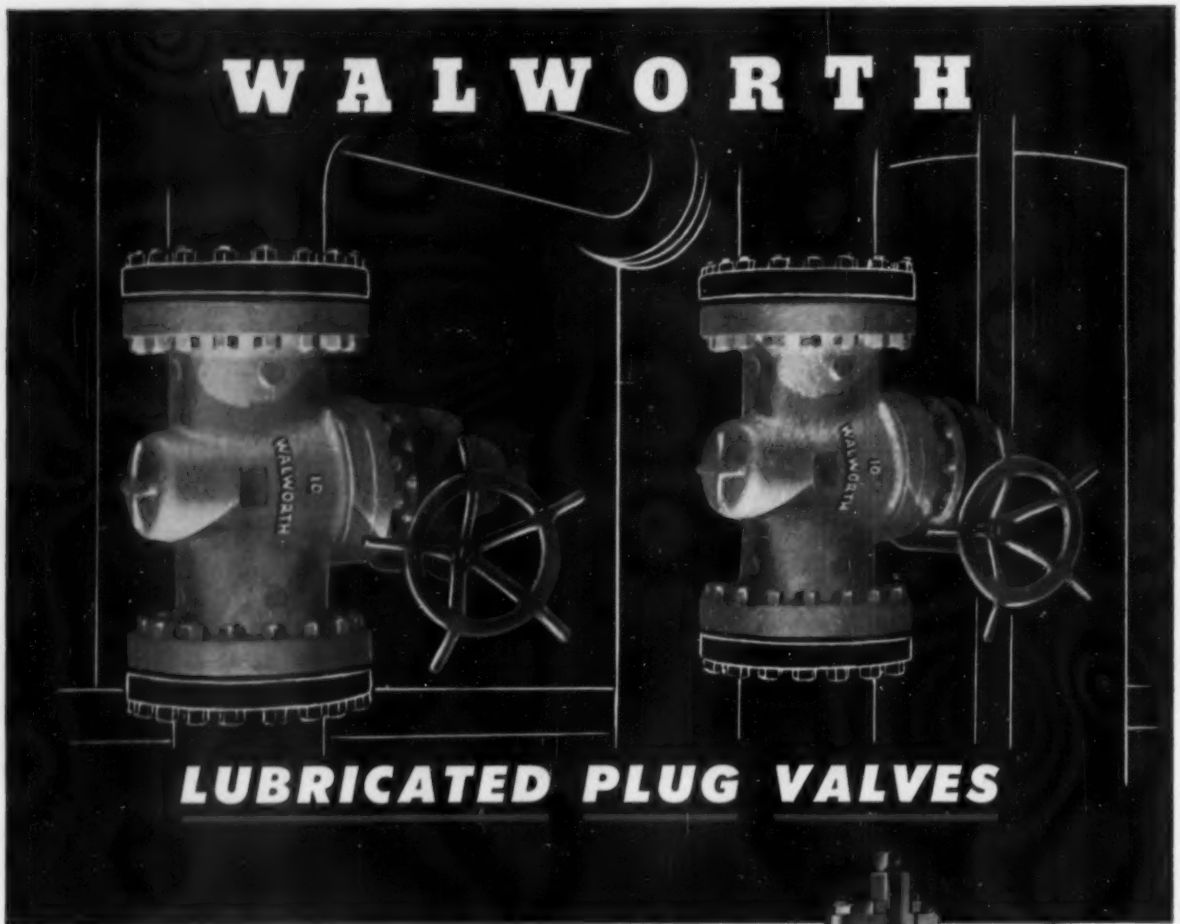
BPA

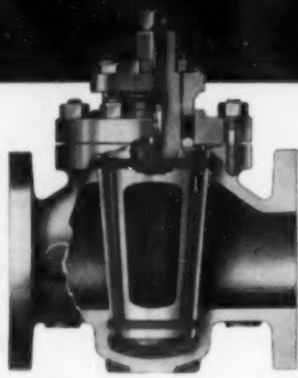
Printed in U. S. A.




## How it works

Steam-water mixture enters the top of the drum through nozzles discharging into an annular space formed by internal baffles. Flow of the mixture is directed downward behind symmetrical baffles around the entire drum surface, maintaining a uniform drum-wall temperature, and then into the Turbo-Separators. The latter contain a center core and vanes which give the mixture a spinning or centrifugal motion, thereby throwing the water to the outer edges of the inner tube. Directly above the directional vanes and cores there is a skim-off lip which directs the water over the top of the inner tube and thence through the annular space to the drum. This is the primary separation stage. The relatively dry steam then passes through two opposed banks of closely spaced corrugated plates, which change the direction of the steam many times and throw out much of the remaining water. This is the secondary separation stage. The third and final stage of purification is accomplished in the screen dryer.



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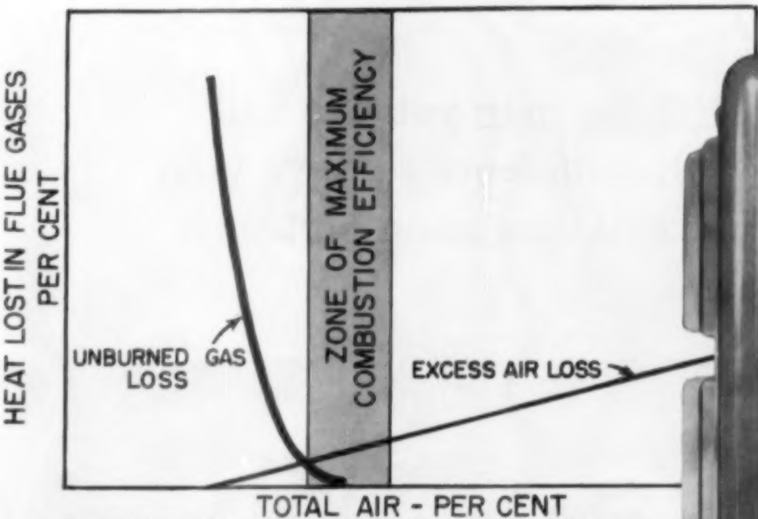



The new Bailey Oxygen-Combustibles Analyzer-Recorder (shown at right) provides a continuous two-in-one check of combustion efficiency by recording both oxygen and combustibles in flue gas. As shown by above chart, both measurements are needed to determine combustion efficiency.

# BAILEY announces . . .
# New 2 in 1 way to measure Combustion Efficiency

The new Bailey Oxygen-Combustibles Analyzer-Recorder gives you a continuing double check on combustion economy. It's fast response measures and records:

**1. Excess air**—regardless of the fuel or combinations of fuels being burned.

**2. The mixing efficiency of your fuel-burning equipment**—by indicating the amount of combustibles in your flue gas, resulting from incomplete mixing of fuel and air.

Combustion efficiency depends upon fuel-air ratio. Too much fuel can be even more costly than too much air. And because of the interdependence of these two factors, no control that measures only one of them can give you complete protection.

Now, for the first time, you can check *both* with a *single* fast acting instrument, using the new Bailey Oxygen-Combustibles Analyzer-Recorder for industrial furnaces, kilns, heaters and boilers.

Fuel economy improves as excess air is reduced—until unburned fuel begins to show up in the flue gas. When this happens, combustion efficiency drops off sharply if there are further decreases in the air-fuel ratio. That's why combustion gases must be analyzed for *both* oxygen and combustibles to get a true indication of efficiency—and that is why Bailey coordinates both measurements on the same chart, to show when excess air may be reduced safely without danger of greater losses from unburned gases.

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Ask your local Bailey engineer for suggestions on application. Equipment details in Product Specifications E65-1 and E12-5. P31-1

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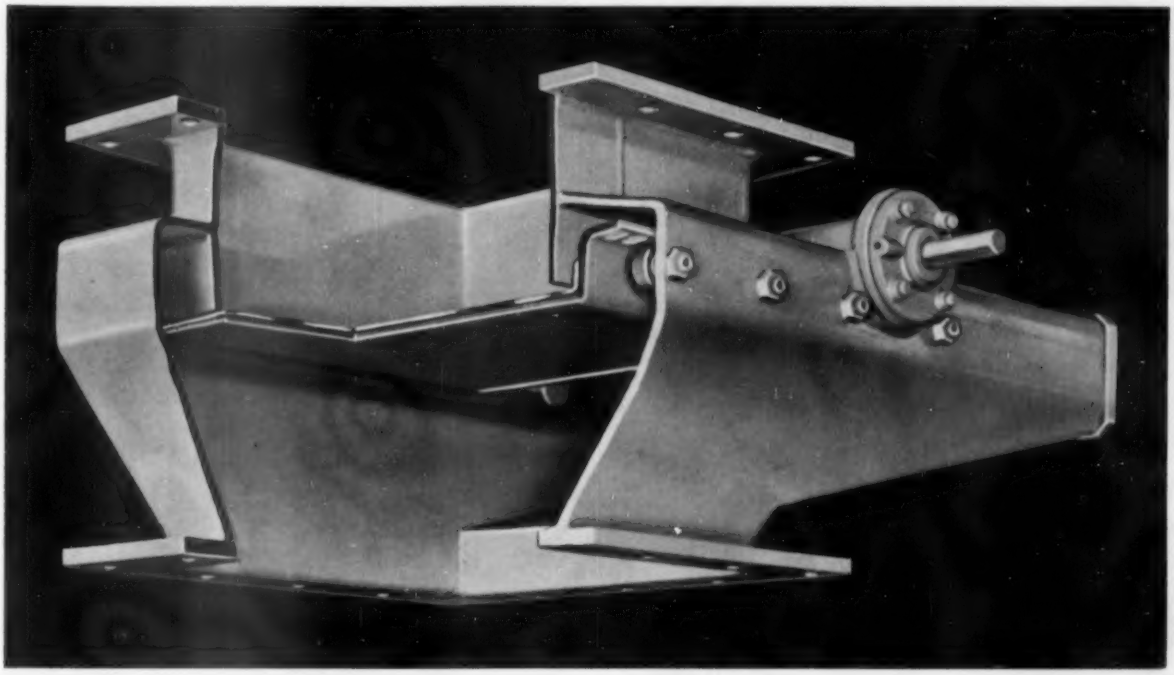


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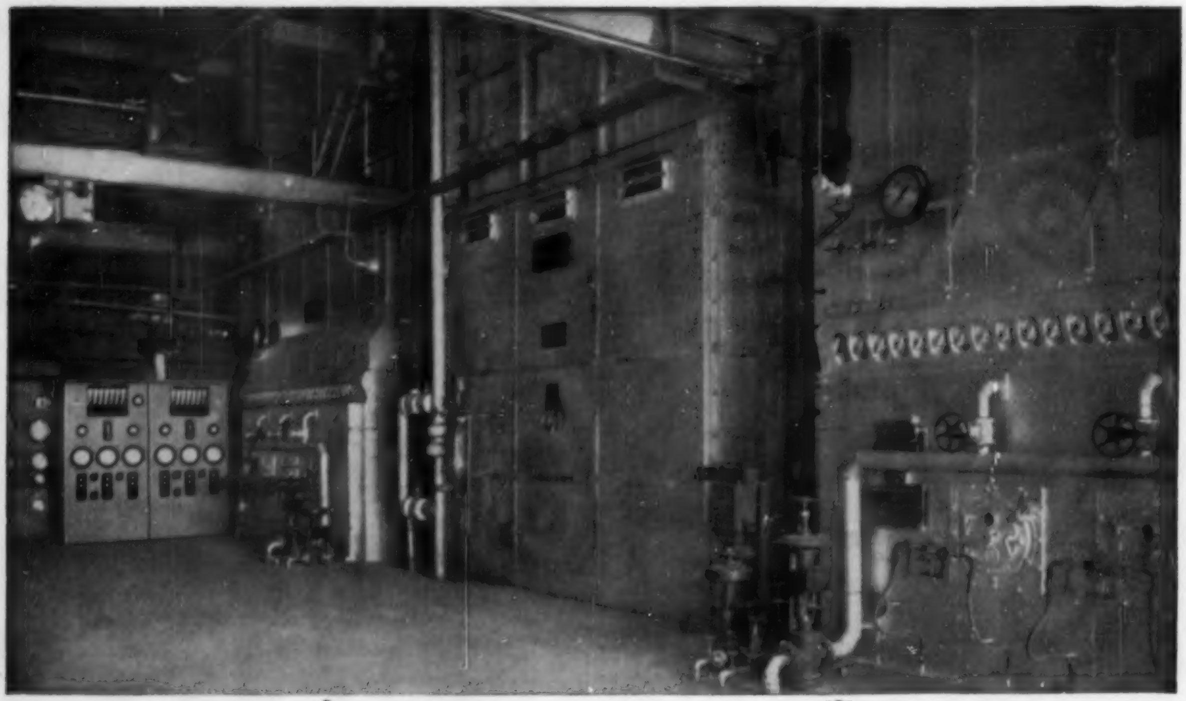

Boiler room at Kansas State College. Republic instrument panel is at left. Boilers are arranged for either gas or oil firing.

# REPUBLIC
## *Automatic* COMBUSTION CONTROLS
## Go to College to Cut Steam Costs

● At Kansas State College, a complete Republic combustion control system, feedwater level controls and instruments automatically operate two 50,000 pounds per hour boilers for maximum combustion efficiency. Fired by either oil or gas, these boilers generate steam at 225 psig and 500°F.

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Whatever the size of your boiler, its draft arrangement, type or types of fuel to be fired and load conditions to be met, there's a Republic combustion control system that can bring these advantages to you. Our engineering staff, with more than 37 years *specialized* experience in combustion control systems, is at your service to help you get the system that exactly meets your needs. For your convenience, there's a nearby Republic field engineer to bring you all the facts. Write and make a date to see him soon.

Instruments on the control panel monitor boiler operation. If desired, the entire combustion system can be operated manually from this panel.

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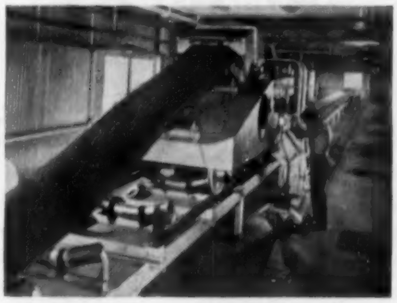
# Bartlett-Snow coal handling at *Green River*

General View of Green River Power Station
Kentucky Utilities Company
Sargent & Lundy
Consulting Engineers

● The illustration above shows the first 60,000 KW unit of a plant that is to be enlarged into a 180,000 KW station. The coal handling equipment which was built, and installed, by us to Sargent & Lundy specifications, includes track hopper; duplex feeder; belt conveyors of 300 ton capacity; surge hopper for the storing out conveyor; crusher, weightometer, and sampling; inexpensive open galleries with hinged covers to protect the belt from the weather; and our newest design of motorized travelling tripper equipped to insure dust-free operation. For maximum efficiency and fixed unit responsibility, let the Bartlett-Snow coal handling engineers handle your next job.



Discharge Chutes of this Bartlett-Snow Motorized Travelling Tripper are Fitted with Plows and Rollers that Open and Replace the Bunker Seal Assuring Dust-Free Operation

View of Open Belt Conveyor Gallery. Protecting Hoods are Hinged on One Side and can be Latched in Either Open or Closed Position

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# POWELL VALVES FOR POWER PLANTS

FIG. 375—Bronze Gate Valve For 200 Pounds W.S.P

FIG. 1793—Iron Body Bronze Mounted Gate Valve For 125 Pounds W.P.

FIG. 19003—900-Pound Pressure Seal Gate Valve

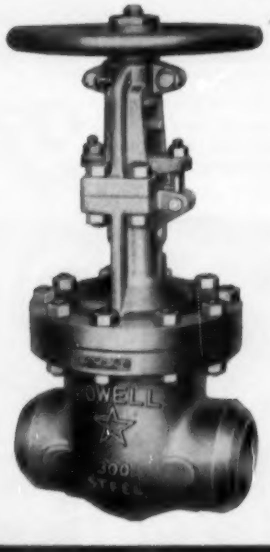


FIG. 3003—Steel Gate Valve For 300 Pounds W.S.P.

POWELL VALVES . . . THE COMPLETE QUALITY LINE . . . POWELL VALVES

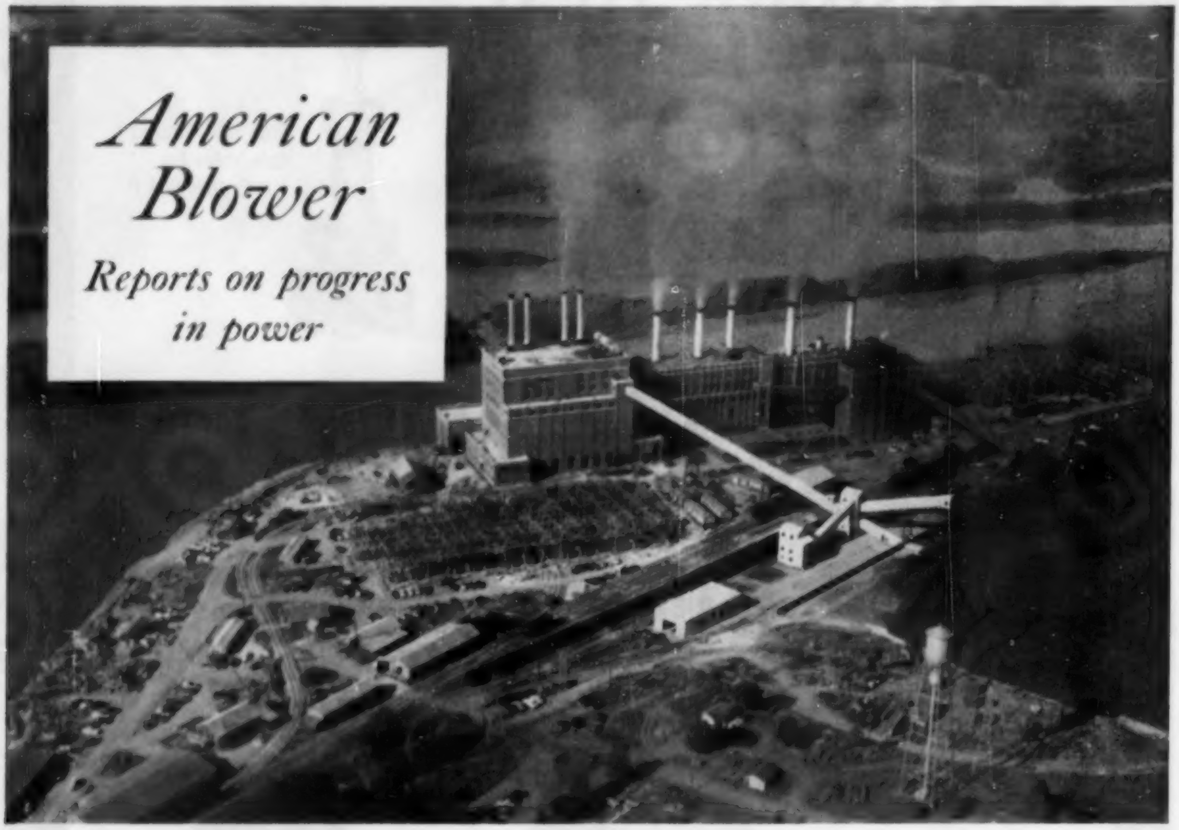
Just name the valve you need for your power plant—Powell can supply it. And you can be certain that every Powell Valve will give you *dependable* flow control.

Shown above are just a few Powell Valves for power plants. Investigate the *complete* line of quality valves that have a proven record of long life and dependable service.

Consult your Powell Valve distributor. If none is near you, we'll be pleased to tell you about our complete line, and help solve any flow control problem you may have. Write . . .

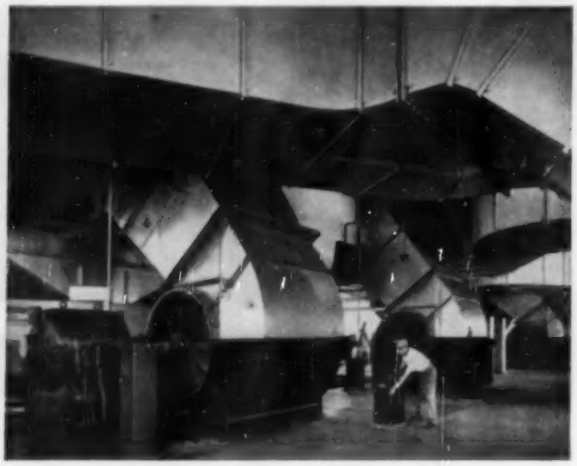
**The Wm. Powell Company, Cincinnati 22, Ohio..... 109TH year**

# From a tiny trickle to a mighty




**1.** Duke Power's Buck Plant (above) near Salisbury, N.C., increased capacity by 250,000 kw in 1953. Two new generating units, recently completed, also added 266,000 kw to the Riverbend Plant near Charlotte, N.C. At the Dan River Plant near Draper, N.C., a new 150,000 kw unit is under construction, to be completed in 1955. Two other Duke Power plants are: Cliffside near Shelby, N.C. and Lee near Greenville, S.C.

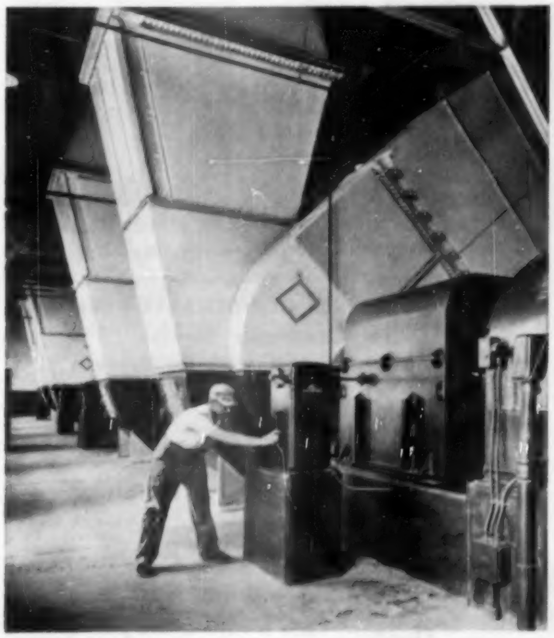
**2.** American Blower Gýrol Fluid Drive – type VS, class 6 – provides smooth, adjustable speed control of a boiler feed pump. It is coupled with a 1750 hp motor in the Buck Plant.



**3.** Four American Blower Forced Draft Fans are installed in Duke Power's Riverbend Plant. Each has a capacity of 143,000 cfm @ 100°F @ 1180 rpm @ 406 bhp.

# 2,211,000 kw–that's Duke Power!

4. Duke Power installed these four American Blower Induced Draft Fans at the Buck Plant. Each is driven through a type VS, class 4 American Blower Gýrol Fluid Drive.



5. Rated @ 234,000 cfm @ 296°F @ 637 bhp, each of these four American Blower Induced Draft Fans at the Riverbend Plant is coupled with an American Blower Gýrol Fluid Drive.

**In its tremendous expansion, another leading power company chooses American Blower equipment**

On April 1, 1904, a power line from a small hydroelectric plant at India Hook Shoals, S.C., was completed to Rock Hill, S.C. This was the simple beginning of the Duke Power Company system . . . a system that today serves over half a million customers in a 20,000-square-mile area in the Piedmont Carolinas – supplying electricity for some 35% of the nation's textile spindles . . . a system that through continued expansion will have an estimated capacity of 2,211,000 kw in 1955!

Planning far ahead of customers' needs is basic to this progressive, investor-owned utility. During the eight years from 1946 through 1953, Duke Power spent $231,000,000 to expand facilities, including $6,000,000 for the South's first steel-tower 230 kw line. Present plans call for additional expenditures, through 1964, of $30,000,000 annually. Duke Power is surging ahead with a dramatic fifty years of generating electricity behind them!

Supplying dependable air handling equipment and Gýrol Fluid Drives is the important part American Blower plays in Duke Power's tremendous expansion. (See pictures and captions.) It's a big role, one that is being duplicated in leading power and industrial plants everywhere.

If *your* future calls for expansion or modernization, talk over your plans and problems with an experienced American Blower representative. He can recommend efficient, economical equipment—including Mechanical Draft Fans, Fly Ash Precipitators, Dust Collectors, Heavy Duty Steam Coils and Gýrol Fluid Drives for boiler feed pump and fan control. Call your nearest American Blower Branch Office.

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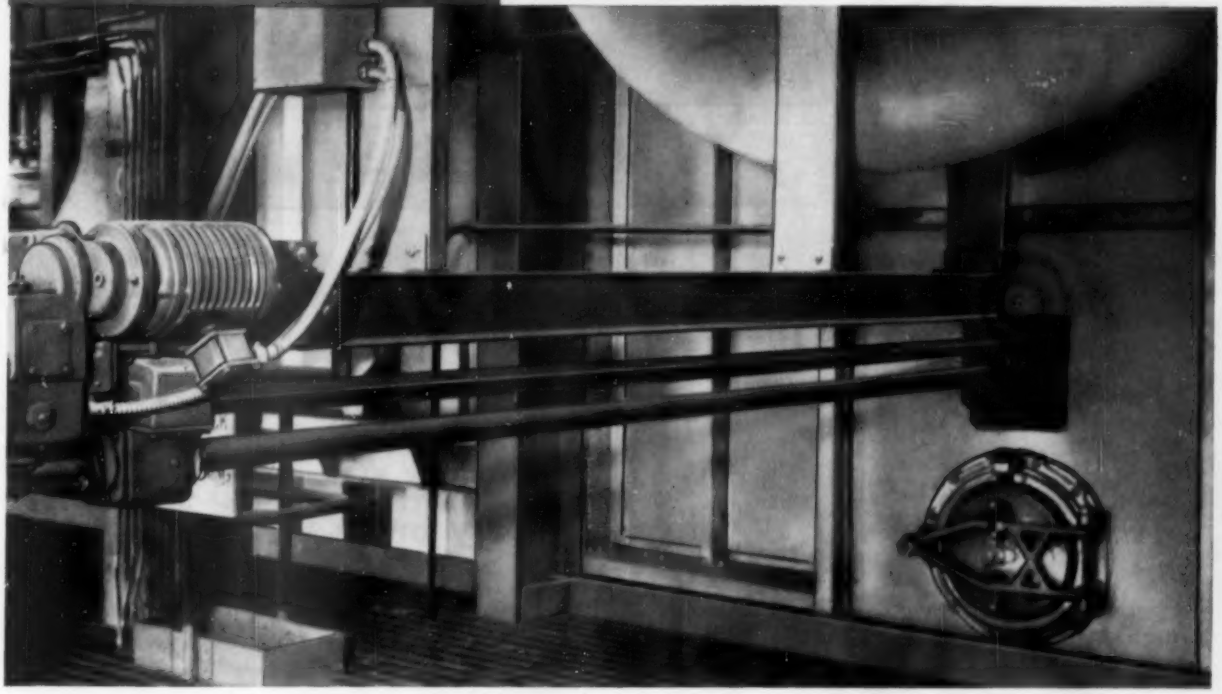
# Retracts clean better



Vulcan Long Retracts clean better—with fewer outages, at lowest cost. They are engineered for optimum performance under varying conditions. They work equally well at any angle. They give you the benefit of dual-motor operation—one motor to traverse the lance, a second to rotate it. *Rotation is always in the same direction.* Repeated cleaning cycles result in an infinite number of double-helix paths that continually broaden the cleaning coverage. Lances can pass through as little as four inches of tube clearance. Write for Bulletin 1002.

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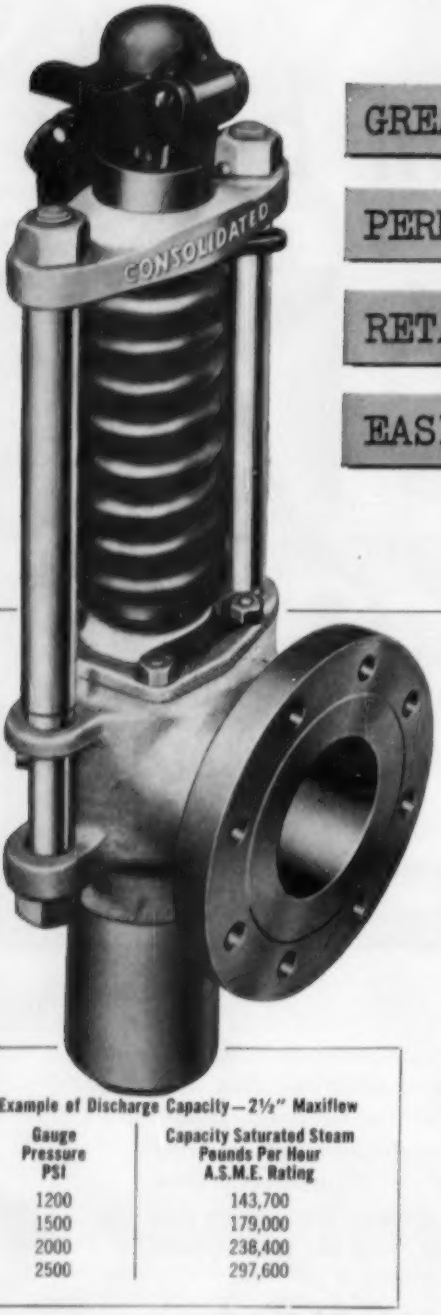
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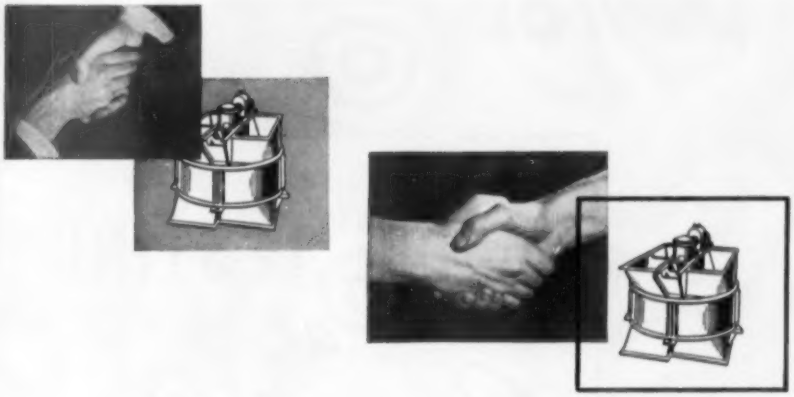
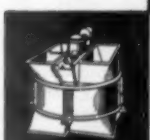


# *Why your Ljungstroms are so efficient*

# *—year after year*

Air Preheater Corporation Field Engineers aim to visit every Ljungstrom Air Preheater in this country at least once a year. Their main objective is to increase availability and assure you a maximum return on your investment. They are always available for consultation.

This is just another reason why the Ljungstrom Air Preheater is *the most economical heating surface on the modern boiler.*

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# MODERN METHODS
# of Coal Handling

**14 TONS OF COAL AT A TIME** is stockpiled or reclaimed at an Eastern utility by this HD-20 Tractor with special Baker coal blade. Blade design takes advantage of tractor's big 175 net engine hp, permits moving up to 15 percent more coal than with regular blade. Repeated trips of 25-ton unit over stockpile compacts coal, helps prevent spontaneous combustion.

**COKE IS STOCKPILED AT A STEEL MILL** leveled and compacted by this Allis-Chalmers 72 drawbar hp HD-9 Tractor — then is reclaimed as needed for the plant. Wintertime operation no longer is hindered by freezing of coke surface as it was with system previously used.

**VERSATILE HD-9G WITH 3¾-YD. (2.8-TON) BUCKET** builds storage pile of coal brought to Midwest industrial plant by truck. These coal-handling buckets are available for all four Allis-Chalmers tractors, from 2-yd capacity on the HD-5G to 7-yd on the HD-20G. Blades and other attachments are interchangeable with buckets to widen the usefulness of Tractor Shovels.

**COAL IS RECLAIMED AS NEEDED** from the storage pile of a Michigan industrial plant by this Allis-Chalmers 109 drawbar hp HD-15 Tractor with Gar Wood straight blade and wings. It moves about 9 tons of coal at a time. Unit also stores coal, which is brought in by rail. Tractor handling of coal is flexible, can either supplement existing facilities or take over complete job. Permits adding storage areas without installing costly conveyors, tracks, etc. — or abandoning them without leaving money tied up in idle equipment.


**Find out more about how Allis-Chalmers equipment can improve your coal handling at lower cost. See your Allis-Chalmers dealer for a demonstration right at your plant, or ask to see the color film showing coal-handling equipment at work. Also, send for free booklet, "Economic Coal Storage."**

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# COMBUSTION

# Editorials

## A Solemn Reminder

Advances in the art and science of engineering inherently involve certain risks. The success of any given design is dependent upon the extent to which these uncertainties can be forecast, appraised and evaluated. In many instances sufficient data are available to make actual calculations of the uncertainties, hence the term calculated risk. But there are others in which the designer can have only a qualitative sense of the uncertainties and must base his decisions on what might be considered faith in good engineering judgment.

During the year 1954 there were at least three major breakdowns which serve to remind the central station industry of the inherent risks in an advancing technology. Early in the year there were several accidents at the recently commissioned R. L. Hearn Plant of Ontario Hydro. Late last September a mechanical failure within the generator at the 150,000-kw Unit No. 1 at Cromby Station of Philadelphia Electric Company caused considerable damage during a routine test shortly after that station had been placed in service. On December 19 there was a serious accident to the turbine of a recently installed unit at the Ridgeland Station of the Commonwealth Edison Company, in which two operating engineers were killed and damage to the plant was estimated as high as $10,000,000.

This is not a time to become alarmed and fearful of safety conditions in central stations. By the very rarity of their occurrence, such accidents attract a great deal of attention. Undoubtedly the lessons learned therefrom will be widely publicized in accordance with the admirable tradition of the utility industry of making such information generally available. The lives so tragically lost at Ridgeland cannot be regained, but the memories of these supreme sacrifices in the line of operating duty serve as a solemn reminder of the inherent risks in engineering advances.

## Sulfur Elimination From Fuels

The recent Special Study Conference sponsored by the Institution of Mechanical Engineers in London last October on sulfur removal and recovery from fuels brought together a number of European authorities to exchange views on a subject held to be of prime interest in their countries and of more than passing interest in our own.

The Conference brought out that the main source of indigenous sulfur in Great Britain is anhydrite and gypsum. The 1954 requirements measure 115,000 tons of regular sulfur and 250,000 tons of acid-making sulfur of which total 75 per cent is imported. Yet the coal burned annually in Great Britain contains over 3 million tons of sulfur and only 5 to 6 per cent of it is recovered. Similarly petroleum refined in Great Britain today, amounting to 25 million tons per year, has an average of 2 to 3 per cent sulfur or about 0.6 million ton which could be tapped. But again only 5 to 6 per cent of the available sulfur is recovered from this source. To the Conferees these statistics represented a direct challenge.

The challenge as they saw it was not only the recovery of sulfur from fuels but the elimination or reduction of oxides of sulfur in the atmosphere. A number of papers were presented on the occurrence and removal of sulfur in coal and oil and twice as many on the removal of sulfur from fuel gases. This division is an understandable one in that air pollution control problems have forced a number of industries over the years to inquire into the role and the effect of sulfur products discharged into the air with stack gases.

From the economic standpoint there appeared to be a natural limit to the extent to which sulfur could be removed from coal and oil. Further, the cleaning of power station gases was still uncommon although at least two processes exist and a third(ammonia washing) was said to show experimental promise. The existing processes in Great Britain cost from $1.12 per ton to $1.96 per ton of coal burnt. The ammonia process held forth a hoped-for cost of 28 cents per ton of coal burned with an outside possibility of showing a profit eventually.

While the general tone of the Conference promised no quick solution the assembly in a common forum of representatives of the different industries involved, fuel producers and fuel consumers of all stripes, strikes a most encouraging note. The problems sulfur presents in fuel burning and atmosphere pollution are so diverse and involve so many human activities that progress in their control can only come from the pooling of the various talents and viewpoints concerned.

# The Present Status of Steam Properties*

By FREDERICK G. KEYES and JOSEPH H. KEENAN
Massachusetts Institute of Technology

**With the advent of the supercritical pressure cycle upon the power plant scene, questions have been raised concerning the adequacy of existing steam tables. What are the limitations upon extrapolated data? How long will it take to perform the painstaking experimental work necessary for extending the present tables? As evidenced by the Commentary in our January 1933 issue, COMBUSTION has shown a continuing interest in steam table research and is proud to be among those publishing this ASME Annual Meeting paper by the distinguished originators of the U. S. Steam Tables.**

The Third International Steam Tables Conference held in the United States in 1934 reviewed the reports of investigations of steam properties submitted by the investigators from the United States, England, Germany and Czechoslovakia. The reports considered were based upon some ten years of measurement effort begun under the auspices of the ASME, following a meeting of scientists, engineers, and turbine designers in Cambridge at Harvard University during June 1921.

The result achieved by the third conference of 1934 was the definitive International Skeleton Steam Tables, accompanied by estimates of accuracy, or "tolerances," and included the designation of fundamental units, definitions and conversion relationships.

The primary purpose to be served in devising the skeleton tables was to designate at comparatively large temperature and pressure intervals values pertaining to the saturation state of water substance and the superheat region over the entire ranges of these variables which had become accessible to the scientific investigators. The data following from three independent investigations of vapor pressures from 0 to the critical temperature (374.15), the phase boundary volumes of the liquid, the heat capacities of the saturated liquid, and the heats of evaporation were available. In the superheat the enthalpies were available from independently conducted measurements to 550 C (600 C was reached by our British colleagues) and to pressures of 300 atm. The heat capacities of the superheat region were also available from direct measurement to 450 C and to pressures of 200 atm. Joule-Thomson measurements were available over the range 125 to 347 C and to 40 atm. Measurements of the volumes of the compressed liquid phase had been made to nearly 350 atm to the critical temperature. The data on volumes of the superheat extended from 2 cc per g to 150 cc per g, and to temperatures of 460 C. This extensive ensemble of painstaking experimental investigations comprised the basis of the skeleton tables. The published tables became available to anyone, anywhere, for the preparation of detailed steam table which would be considered "International Tables" provided the values contained therein were within the tolerances set by the Third International Conference group.

It was the cherished hope of the conferees in 1934 that the limits of temperature range, 550 C (1032 F) and of pressure, 350 atm (5000 psia) attained in the investigation of water substance would serve all requirements in the science and art of power production for the lifetime of the youngest conference participants. The hope has not been realized for now we envisage the need for accurate data at even higher temperatures and greater pressures.

Nor is this all, for we require far more exact and verified data for the viscosity and thermal conductivity of water substance than exist at present. Finally, it is now highly desirable that a comprehensive investigation be pursued on the relation of the International scale of temperature to the thermodynamic scale. In the scientific sense it is only the latter scale which finds full logical justification when employing the laws of thermodynamics. Indeed we now know, thanks to James A. Beattie's gas

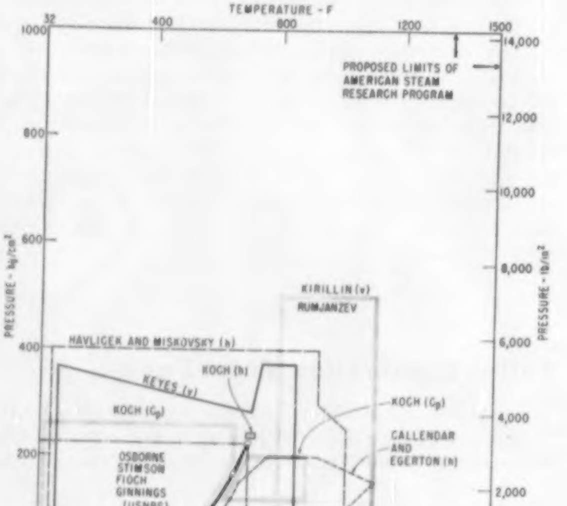



**Fig. 1—Pressure-temperature diagram showing limits of work to date and proposed limits for a future research program**

* Contributed by the ASME Research Planning Committee and presented on November 29, 1954, at the Annual Meeting of The American Society of Mechanical Engineers, New York, N. Y. Published complete except for section entitled "The Viscosity and Thermal Conductivity of Water Substance."

thermometric investigations, that the available steam data is consistent in the thermodynamic sense, although there are deficiencies in our knowledge of the scale relationship above the range 0 to 444.6 C.

The satisfying success of the earlier international cooperative effort to perfect our knowledge of water substance, culminating twenty years ago, suggests that the present need for data at higher temperatures and pressures may find fulfillment under a similar organization. It is with this hope that the present statement has been drawn up. In what follows a brief presentation is made of the extent, in terms of the variables, pressure and temperature, of our existing knowledge. The extension to larger values of these variables through a form of international organization adapted to present circumstances is urgent.

Since the 1934 International Conference, considerable new data and important correlations of experimental findings have been reported. Thus may be cited (1) very accurate measurements of essentially the heat of evaporation between 0 and 100 C (August 1939); (2) the development of the means for measuring the change of enthalpy with pressure at constant temperature with data in the range 40 to 125 C, leading to exact values of volume in a region inaccessible to accurate measurement by direct means; (3) the accumulation of data relating to the infra-red spectrum of water vapor in the ideal gas state have been computed; (4) G. C. Kennedy's $p$-$v$-$T$ relationships in water to high temperatures and pressures; (5) the direct measurement of $p$-$v$-$T$ properties of steam between 531 and 600 C, and to 500 atm; also, (6) data for $C_p$ in the superheat. These valuable contributions to our knowledge of equilibrium states have been supplemented by (7) much work on the transport properties, viscosity and thermal conductivity so vitally important in the applications of heat transfer theory. The results now available, however, appear to require verification.

The proposal is advanced as a point of departure for discussion that additional measurements be obtained to extend the temperature range of verified data to 800 C (1500 F) and 1000 atm (15,000 psia). The quantities proposed for measurement are (1) the enthalpy for steam from 500 C and (2) the $p$-$v$-$T$ properties from 500 C, not alone by direct measurement but from measurement of (3) the enthalpy change with pressure at constant temperature. This differential quantity is a direct measure of the departure of a fluid from the ideal gas state and leads to a valuable confirmation of the accuracy of the directly measured $p$-$v$-$T$ properties. The apparatus for measuring the enthalpy change with pressure can be designed to permit (4) the measurement of specific heats, and (5) Joule-Thomson coefficients.

In addition to the foregoing equilibrium quantities, it is proposed that the viscosity of steam be measured to at least 800 C and to pressures of 1000 atm. Similar ranges are proposed for the thermal conductivity.

The relation between the International Scale of temperature and the thermodynamic scale has been determined recently to the sulfur boiling point. The results of the foregoing scale investigation should, however, be confirmed and extended to the silver calibration temperature, 960.8 C.

Fig. 1 shows in pressure-temperature coordinates the areas covered by the investigations of the first international effort, and also included later investigations to date. G. C. Kennedy's work, which extends to 1000 C (1832 F) and to nearly 2500 atm (37,000 psia) is not represented in Fig. 1. Professor Kennedy is verifying

## Commentary by Joseph H. Keenan

### From The Sidelines

I do not usually seek my recreation in technical meetings, but these A.S.M.E. steam research sessions are different. The last one settled all we shall want to know for a long while about the vapor pressure of water. But then, every steam research session has settled some important issue. Once it was the design of a 1/7500th horsepower pump. Osborne needed one for the innards of his little copper-nickel boiler with the gold-gasketed joint. The pump had to be efficient, not just a paddle wheel. And when things got going that pump stood several years of operation, its tiny shaft turning in a water tight packing that sealed against boiling water at 800 pounds per square inch. Failure came only when the time had arrived to build a new apparatus. What more could one ask of any design?

I saw the experimental data start to trickle in as I sat through those December meetings. A few Joule-Thomson coefficients appeared in 1922. In 1923 these measurements from Harvard had worked their way into high pressure regions. Before that we had no experimental knowledge of superheated steam above 250 pounds per square inch, but Davis and Kleinschmidt had now pushed on to almost 600 pounds. Two years later these data reappeared, metamorphosed into a steam table.

In 1927 Keyes spread before us fifty-two volume measurements of a consistency unprecedented in measurements on superheated steam. The highest pressure investigated was 3900 pounds per square inch, the lowest was 1400 pounds. Here was no hesitating approach to the formidable region of high pressures, it was a bold invasion of its fastnesses. It took some time to coax Keyes and Smith down to the more civilized regions below a pressure of 1400 pounds. They had made measurements at 5200 pounds per square inch and had calibrated their pressure gages up to 8400 pounds before they condescended to enter more prosaic territory. Back in 1927 they had not yet closed the large gap between 600 and 1400 pounds per square inch, but they had triggered off the next steam table development.

Two years later Keyes closed the gap and was proceeding farther on his southerly course. Experimental equipment and technique were being perfected. His first bomb of pure nickel was a source of some annoyance because its walls oozed minute quantities of non-condensible gases into the steam space. It finally ruptured, making way for the use of the more satisfactory stainless steels. The constant temperature bath surrounding the bomb was made ten times as constant, thermometry was improved, the point of separation between the vapor in the bomb and the liquid in the connecting tubes was more sharply defined. And so it happened that a year ago Keyes and Smith told us of a most extraordinary year's work, covering in twelve months the entire range of all their previous experimentation. Suiting equipment and method to each particular region they measured with a precision beyond their own previous performance all the way from 200 pounds per square inch to 5400 pounds. Less spectacular as exploration, perhaps, than some of their earlier work, it was nevertheless the most impressive body of experimental data on superheated steam that had ever been produced in the course of one calendar year.

In the meantime Osborne and his colleagues from the Bureau of Standards were telling us about water and its vapor up to 800 pounds per square inch. Their early descriptions of their methods contained frequent reference to alpha, beta and gamma experiments. But later this Hellenic abecedarianism gave way to the less cryptic discussion of latent heats and enthalpies. They gave us the calorimetric properties of saturated water and its vapor to a precision of one part in 2000, and they deduced through the Clapeyron relation specific volumes of saturated vapor which agreed extremely closely with those reported by Keyes and Smith.

Experimental data from Germany, from England, from Czechoslovakia, analytical studies from everywhere, in fact all the varicolored threads that make up the fabric from which steam tables are made were woven together at the annual meetings.

There are signs and portents foreshadowing an early close of the American steam research program. It should not be so. An organization of skill and experience should not be dispersed until it has acquired all information within its reach. I hope to hear Osborne a few years hence tell us about the specific heat of superheated steam to his usual one part in thousands. I look forward to the reports from Keyes on Joule-Thomson and constant temperature coefficients in the low-pressure range when we need them most. I expect to see him build the structure of the thermodynamic temperature scale which must soon replace the platinum standard. December will remain the prominent month in my calendar, if steam research goes on.

Joseph H. Keenan

Stevens Institute of Technology

COMBUSTION—January 1933

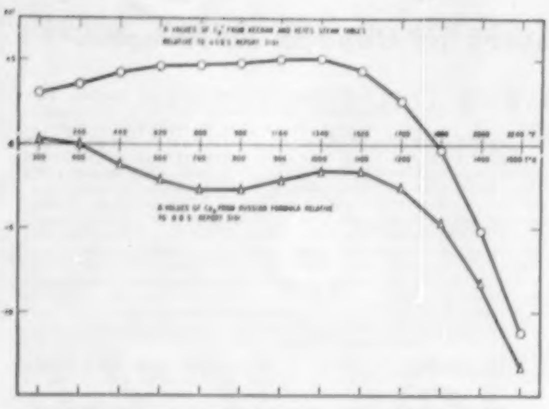


**Fig. 2—Variations in $C_p°$ with respect to National Bureau of Standards Report No. 3103**

his measurements on steam, particularly in the region of immediate interest for steam tables. In consequence of this circumstance, these extensive measurements will be reviewed at a later date. The reported results of investigations undertaken to test the thermodynamic consistency of the existing body of experimental results, and making use of the temperature scale comparisons to the sulfur point (444.6 C) are satisfying. It follows therefore that new investigations extending the old limits of pressure and temperature may start out with a tested array of experimental findings to 550 C and about 350 atm. In addition to this encouraging background the correlating equations evolved in dealing with the existing data will serve to provide reasonable "expectations" of magnitudes in the extended region. Thus the details of the design of measuring equipment can be determined with the advantage of knowing the order of magnitude of values sought.

The U. S. Steam Tables (J. H. Keenan and F. G. Keyes, "Thermodynamic Properties of Steam," John Wiley and Sons Inc., New York, 1936) was compiled with the knowledge that definitive values for $C_p°$ could not be had until further data were available relative to the infra-red spectrum of water vapor. This definitive information is now available[1] and Fig. 2 will convey an impression of the differences in $C_p°$ used in two steam tables relative to National Bureau of Standards values, while Fig. 3 represents differences in the enthalpy quantity $\int_{T_0}^{T} C_p° \, dT$ based on the definitive $C_p°$ values and the same integral derived from the values of $C_p°$ employed in the U. S. Tables and the recent (1951) Russian Tables. At the top of the figure the differences of the 1 kg/cm² enthalpies as tabulated in the two foregoing tables are exhibited. The Russian Tables make full use of the International Skeleton Tables of 1934, using $C_p°$ values resulting from a Russian treatment of the spectral data. The Russian Tables tabulate values to 700 C (1292 F) and 300 kg/cm² (4270 psia). The latter tables also contain detailed tables for viscosity and thermal conduction based exclusively on Russian investigations of these transport properties.

The tabulated enthalpies for several constant pressures from the U. S. and Russian Tables have been compared and the differences appear in Fig. 4. A similar chart of the volume differences is represented in Fig. 5.

In 1950 a paper appeared (by W. A. Kirillin and L. L. Rumjanzev in *Elektritscheskije Sstanzii*, Vol. 21, No. 12 pages 8–14) giving values of pressure and volume at six temperatures, 431.34 C (808 F) to 600 C (1100 F), and to pressures of 500 atm (7100 psia). These data provide an extension in temperature of 140 deg C and in pressures of some 150 atm over the limits of the directly measured values of volume available to the 1934 conference. Fig. 6 gives an impression of the relation of these new measurements to similar values computed from the Russian Tables equation of state. Definite knowledge is lacking regarding the use of the new Russian volume data in preparation of the 1951 tables.

Fig. 7[2] gives a survey of comparisons representing

[1] National Bureau of Standards Report No. 3103.

[2] Fig. 7, has been reproduced from National Bureau of Standards Report No. 2535, Fig. 2, of that report.

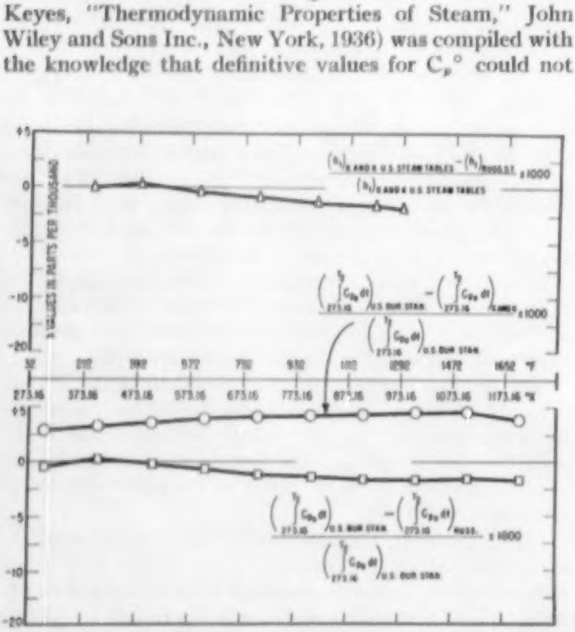


**Fig. 3—Differences in enthalpy quantity with respect to Bureau of Standards, Keenan and Keyes and Russian data**

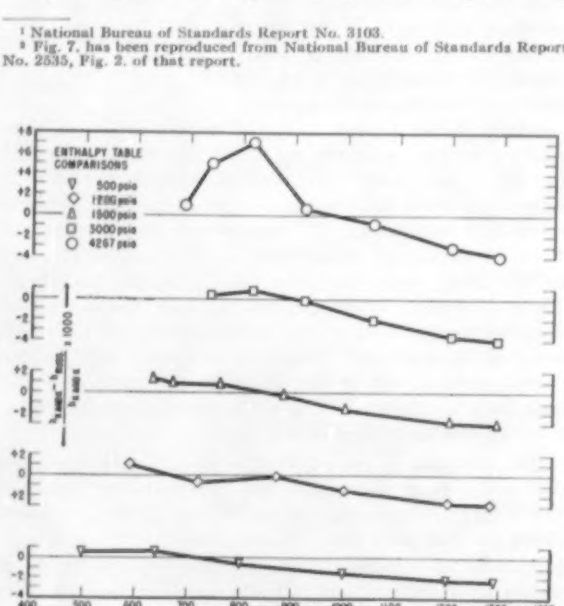



**Fig. 4—Comparisons of enthalpy values in U. S. and Russian tables**

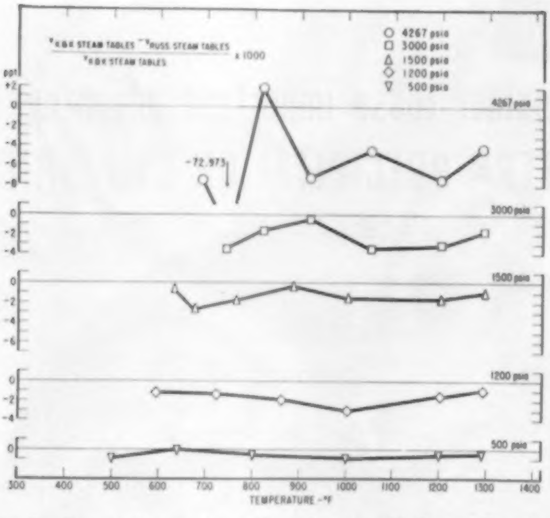



**Fig. 5—Comparisons of specific volume in U. S. and Russian tables**

differences between the reported pressures of the recent Russian $p$-$v$-$T$ measurements and pressures computed from an equation of state based on the Skeleton Tables $p$-$v$-$T$ data. Fig. 8 is a graph comprising pressure differences between the Russian data and pressures computed from the equation of state.

*Conclusions*

The present status of the 1934 International Skeleton Tables data may be summarized as follows:

1. The accuracy of the data is established by the test of thermodynamic consistency when the test is carried out employing the results of the recent experimental comparison of the International scale temperature with the thermodynamic scale.

2. The additional experimental data reported for water substance since 1934 indicates no trend which in any way reflects against the accuracy of the 1934 table. There is an exception, however, in the case of the 1950 Russian data which extends beyond the 1934 superheat volumes in temperature and in pressure. Pressures computed using the equation of state based on the Skeleton Tables superheat data fail of agreement with the new Russian data, being smaller by the order of one per cent.

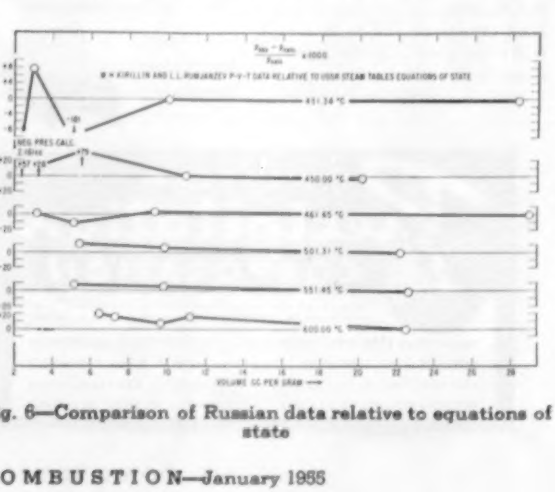



**Fig. 6—Comparison of Russian data relative to equations of state**

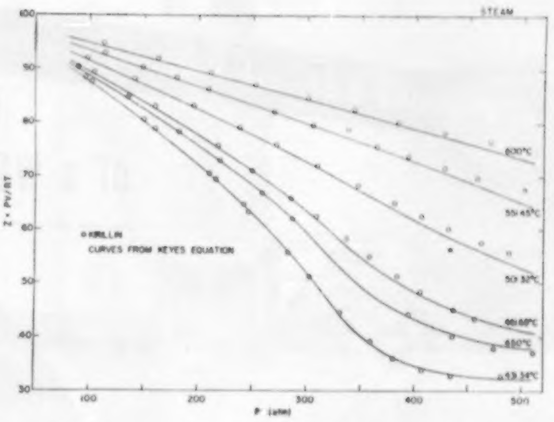



**Fig. 7—Comparison of calculated and experimentally derived compressibility factors**

3. The need of additional experimental data extending beyond the range of the 1934 Skeleton Tables is urgent, not alone for present design needs but for turbine design suited to even higher pressures and temperatures. The higher limits proposed are 800 C (1500 F) and 1000 atm (15,000 psia). With contemporary materials and the experience accumulated earlier, together with the 1934 data of proved accuracy as a base upon which to build, these very high limits are believed attainable.

4. The design treatment of heat transfer equipment depends upon reasonably accurate data for viscosity and thermal conductivity. It is imperative that the present discordant array of transport quantities be disposed of through new research. The viscosity and thermal conductivity should be known at low pressures with an accuracy of at least one per cent to 800 C and to pressures of 200 atm to temperatures of 400 C. The pressure effect falls so rapidly with temperature increase that it need not be measured to 800 C.

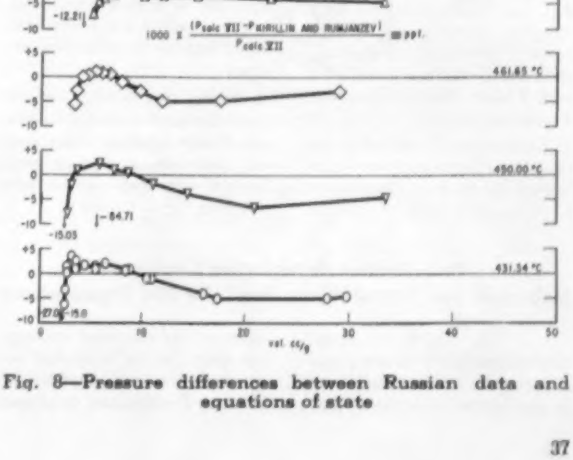
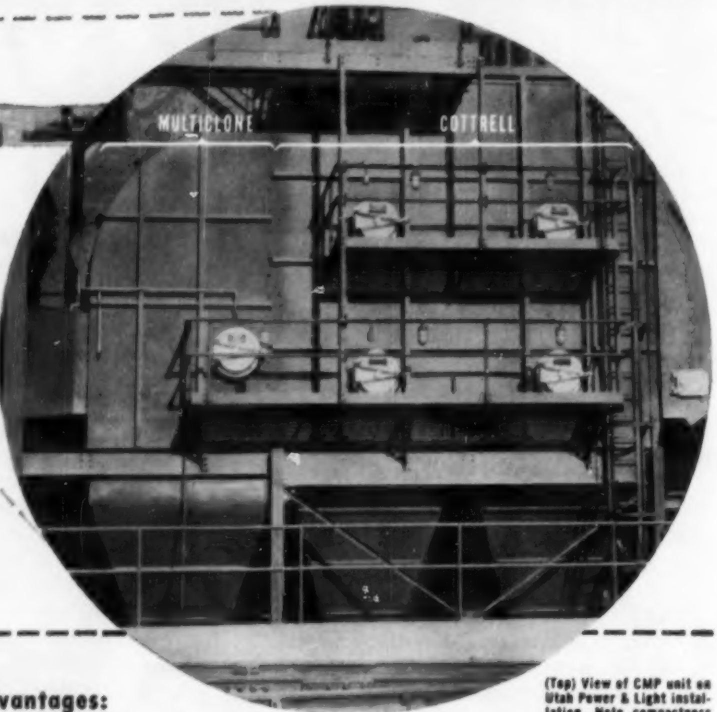



**Fig. 8—Pressure differences between Russian data and equations of state**

## Planning A Fly Ash Recovery Installation?

# Consider these important advantages of a WESTERN PRECIPITATION CMP UNIT!




(Top) View of CMP unit on Utah Power & Light installation. Note compactness of unit. (Above) Close-up of same installation.

**IF YOU are planning the installation of any type of fly ash recovery equipment—mechanical or electrical—it will pay you to investigate the extra advantages to be gained by installing a CMP Unit designed, engineered and constructed under *one* responsibility by Western Precipitation Corporation—*leaders in both electrical and mechanical recovery fields!***

## Combines Mechanical and Electrical Advantages:

**A CMP (Combination Multiclone-Cottrell Precipitator) Unit combines—in one compact installation—both mechanical and electrical recovery principles, so that maximum benefit is obtained from the advantages inherent in each method. The MULTICLONE section centrifugally cleans the gases of the larger and heavier fly ash particles (down to a few microns in diameter) . . . and the COTTRELL Precipitator then electrically removes the very small particles remaining in the gases. This combination arrangement has important advantages:**

**1.** Using the MULTICLONE for cleaning out the heavier particles permits the bulk of the recovery operation to be performed with relatively low-cost equipment.

**2.** Using the COTTRELL for final clean-up insures unusually high recovery efficiency—approaching theoretically perfect, if desired—with a high efficiency, compact Precipitator unit.

**3.** Each type of unit—MULTICLONE and COTTRELL—can be arranged for its most efficient application. MULTICLONES may be connected to each separate boiler, if desired, and their draft requirement cut out when the boiler is down . . . while a central COTTRELL handles all gases and operates at higher efficiencies, with continued low power cost, when one or more boilers are down.

**4.** During soot-blowing periods, or while warming up cold boilers, the MULTICLONE efficiency usually increases, preventing overloads of detrimental carbon from reaching the COTTRELL.

## Only Western Precipitation Combines Multiclone and Cottrell "Know-How"—In ONE Organization!

A vital factor in obtaining maximum efficiency and economy in CMP installations is the proper balance of mechanical and electrical recovery equipment to the individual requirements of *each* application. Western Precipitation is unique in that it not only pioneered the commercial application of COTTRELL Electrical Precipitators over 43 years ago, but also has been a leader for many years in the *mechanical* recovery field with its widely-recognized MULTICLONE Collectors.

*Result*—Western Precipitation has the all-important "know-how" and experience in BOTH fields . . . knows from first-hand experience how to fit the *right* equipment in the *right* place, to do *your particular* job . . . and can provide the complete installation under ONE responsibility and ONE overall guarantee!

**Let Our Experienced Engineers** study your recovery requirements and make recommendations on the equipment best suited to your operations. A wire, phone call or letter to our nearest office places this unique "Know-How" at your service, without obligation!

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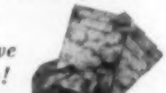

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Fig. 1.—Model of the Pennwood Station of the Sparrows Point plant of Bethlehem Steel Co. illustrates its attractive appearance, compact layout

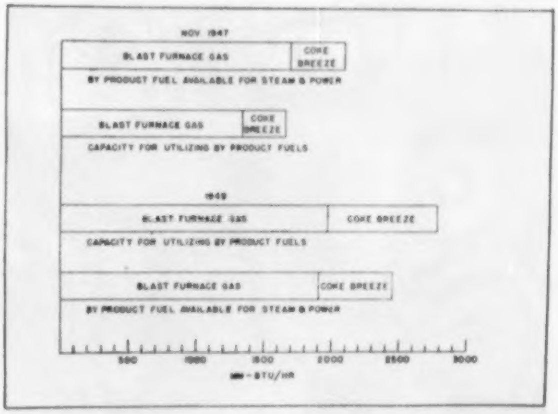


Fig. 2.—Chart above compares byproduct fuels available for power and steam generation for both 1947 and 1949 against installed byproduct fuel-burning capacity

# Bethlehem Steel Balances Energy Needs Against Byproduct Fuel Production

By J. M. SPENCER

Assistant Fuels Engineer, Bethlehem Steel Co., Sparrows Point, Md.

**Immediately after World War II the steel industry expanded its production facilities at a rapid pace. The Sparrows Point Plant of the Bethlehem Steel Co. included an integrated power plant as a vital adjunct to their expansion program and this inclusion has continued to give beneficial operating returns.**

PENNWOOD Power Station, Fig. 1, at the Sparrows Point Plant of Bethlehem Steel Co. owes its existence to a continued desire for better utilization of by-product fuels. Over the years a number of plans had been developed to meet this aim. But for one reason or another all were discarded until after World War II. By 1947, though, studies indicated that the fuel available and the plant electrical load were such that an electrical generating station would be attractive economically. At that time the byproduct fuels were used principally for raising steam at low pressure, for stoves, soaking pits and coke ovens plus gas engines driving small electric generators and blast furnace blowers. An electric generating station would fit into this picture very comfortably and be an excellent means of using up a growing excess of by-product fuels.

*Plant Needs*

Steam needs for a plant the size of Sparrows Point run extremely high. There were in existence at the time of the 1947 studies a number of steam-producing facilities. These units were in addition to the planned Pennwood Station and most of them are still very much in service. They include: (1) two boiler houses that together have nine boilers supplying better than 750,000 lbs per hr of steam at 275 psi with blast furnace gas or oil as their fuel, (2) 26 waste-heat boilers developing some 380,000 lbs per hr more steam at this same pressure level, (3) two boiler houses generating around 250,000 lbs per hr of steam at 175 psi (One of these boiler houses uses coke oven gas and oil for fuel while the other employs coke breeze.) (4) another 8 waste heat boilers delivering up to 120,000 lbs per hr of steam at 175 psi. All told the various smaller boiler houses and waste-heat units then accounted for about 1,500,000 lbs per hr of steam, and still do.

With the plant growth by 1947 providing still greater quantities of byproduct fuels, Fig. 2, the possibility of meeting some of the plant's electrical load with a modern generating station seemed worth while. At that time the electrical load was anticipated to reach a peak of 180 mw with 75 mw of it coming from the proposed Pennwood Station. It has since gone beyond the anticipated 180-mw peak. Along with it there has been an accompanying increase in steam needs. As a result the new power station at Sparrows Point has had two distinct stages of development.

*The Power Plant*

At start-up Pennwood consisted of two 425,000 lbs per hr steam generators firing blast furnace gas, oil or coke

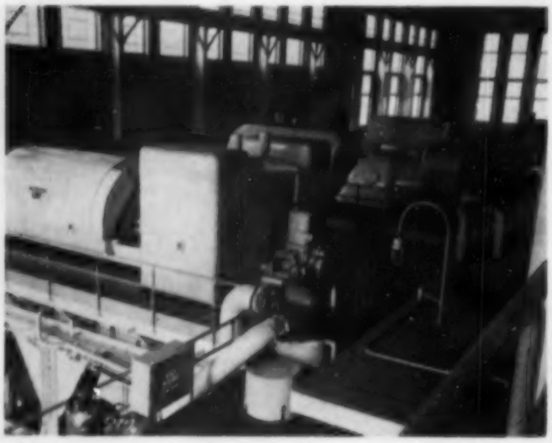

**Fig. 3—Turbine room view shows most recently installed 20,000-kw back-pressure turbine generator, hydrogen cooled, in the foreground**

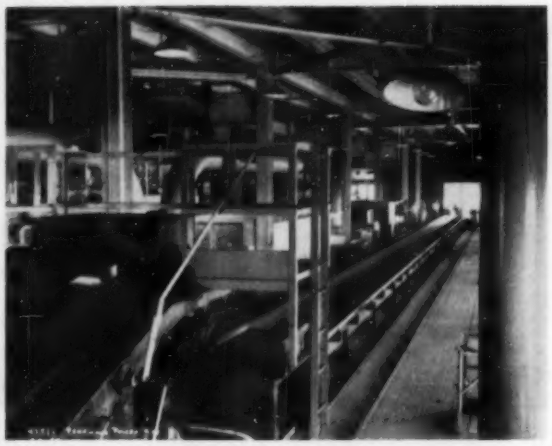

**Fig. 4—Coke breeze is moved across the boiler room for delivery into the plant bunker system by the belt conveyor pictured above**

breeze. There were two ASME preferred standard 30,000-kw hydrogen-cooled generators receiving steam at 850 psig and 900 F, TT, at the turbine throttle. Recently a 20,000-kw back-pressure turbine generator, hydrogen cooled, exhausting to a 275 psi header was added, Fig. 3. At the same time a new 475,000-lb-per-hr steam generator went into service. Like the earlier installation it burns blast furnace gas, oil or coke breeze. The combined boiler and non-condensing turbine ideally meet the requirement of more steam and more electricity. Now the total steam generating capacity of Pennwood amounts to about 1,325,000 lbs per hr of steam as against 850,000 lbs per hr originally and its electrical generating capability totals 100 mw as against the original 75 mw.

The Patapsco River, on which the plant is located, is in a tidal area and at times subject to extreme variations in water level. Past experience had demonstrated that both high and low waters could disrupt operations. So a special attempt was made to meet these problems. The turbine hall floor at Elev. +3.0, is 4 ft below the maximum expected water level and the bottom of the intake tunnel, at Elev. −16.0, stands 8 ft below extreme low water. This arrangement allows a variation in water level of 15 ft, enough, it is felt, to meet any eventuality.

Separate intake tunnels permit a certain flexibility since either one may be isolated by stop logs and the station operated from the other, although at reduced capacity. Condensers, split on the vertical center line, make it possible to clean either half without taking the unit off the line. Automatic chlorinating equipment keeps up the condenser heat-transfer rates.

### *Boiler Equipment*

The steam-generating units can fire blast furnace gas, oil, or coke breeze. A traveling grate stoker, 24 ft by 28 ft, Figs. 4, 5, with overfire air injected at the nose of the rear arch handles the coke breeze. Nine combination gas and oil burners are set in the rear wall of each boiler and feed either blast furnace gas or oil.

Superheat control in the original two 425,000-lb-per-hr steam generators is by means of a bypass damper. A tubular dust collector placed between the economizer and air heater can also be bypassed.

The air heater on each unit has two paths for the forced draft. The upper half supplies air at 600 F for the combination gas and oil burners. The lower half furnishes stoker air at 250 F. An automatic tempering damper admits the necessary cold air quantities to keep the stoker air within limits that will not damage the stoker. This construction also limits the corrosion difficulties on the cold end of the tubular preheaters.

The latest 475,000 lb per hr boiler, Fig. 6, follows the general design principles of its predecessors except it employs a spray desuperheater for superheat temperature control.

### *Present Steam Supply*

Under peak-load conditions the original two boiler and two turbine installations at Pennwood delivered up to 250,000 lbs per hr of steam for auxiliary drives and for bleeding to the 250 psi system. This steam was reduced in pressure through two desuperheating stations, operating in parallel, to 275 psi before admitting it to a 4000-ft-long, 24-in. steam main connecting to the older, low-pressure plant system, Fig. 7.

The new 475,000-lb-per-hr unit has almost all its production available for this low-pressure system after it has passed through the new non-condensing turbine unit. The original desuperheating stations are normally closed, but automatically come into service if the non-condensing turbine trips out.

Station makeup enters the cycle at the deaerating heater. This makeup comes from condensate supplied by consumers on the 250-psi system, thus eliminating a capital outlay for water-treating equipment at the station itself. All treatment now is internal and involves phosphate, sodium sulfite and caustic soda. The pH of the entering feedwater averages 7.5 to 8.0 which is held too low for good economizer life. Recirculating boiler feedwater corrects this condition, though.

The present breakdown of 250-psi steam production for plant needs by the different generating facilities gives Pennwood 9,600,000 lbs per day; the older low-pressure boiler houses, 18,625,000 lbs per day; and the various waste-heat boilers, 8,200,000 lbs per day; for a grand total of 36,625,000 lbs per day.

Fig. 5—Traveling grate stoker, 24 by 28 ft, fires coke breeze. It has an overfire air injection point at the nose of the rear arch. Gas and oil burners mount on rear wall

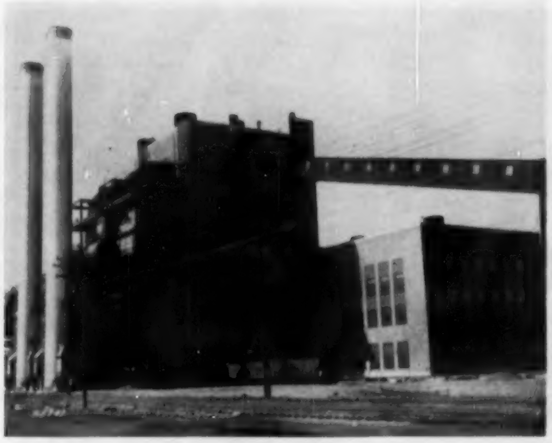

Fig. 6—External view of Pennwood Station shows that all heat recovery equipment for the station, dust collectors, and induced draft fans stand outside

The primary users of steam at high-pressure level are the Pennwood turbine generators. Other turbo generators, mostly for 25-cycle service, turbo blowers and coke oven exhausters are the principal users of 250-psi steam. The miscellaneous users account for the 150-psi steam load although there is a very sizable space heating load in the winter. Table I shows the relation between the major steam requirements regardless of pressure.

*Fuels and Fuel Handling*

Of the various fuels available to meet these steam needs the percentage each furnishes breaks down as follows: blast furnace gas, 60.9%; coke breeze, 14.6%; waste heat, 19.8%; fuel oil, 4.6%; and coke oven gas, 0.1%.

The most important from the standpoint of quantity is blast furnace gas. At Sparrows Point the blast furnace gas system consists essentially of a large main running east and west the full length of the blast furnace section. Each of the nine furnaces discharges its gas into this main and each consumer draws its gas from this main.

Gas in this main is "dirty" or "rough" gas and depending upon its eventual consumer service may be cleaned by passing it through disintegrators or precipitators where the dust loading is reduced to as little as 0.004 grain per cu ft. But in addition to the cleanliness factor, as far as specific consumer requirements go, is the one of priority.

The blast furnace auxiliaries have first call on any gas. Then the production units, such as soaking pits and coking ovens, get theirs. And finally the steam-generating equipment and the gas engines. The reasoning is straightforward. The coke ovens can use coke oven gas and the steam boilers, oil. The gas-driven electric engines may be scheduled off if gas supply proves inadequate but if they are left running their priority is equal with the gas-driven blowers on the blast furnaces.

Since the gas mains serve as the only storage space for gas and gas production varies from considerable to relatively little a good system of controls is provided. These controls serve two prime functions, dispatching and safety. Actually the two functions interlock.

For example the prime requirement of any safety control is to protect the gas distribution system and the gas consumers from either extremely high or dangerously low gas pressure. The gas is toxic in nature and is piped into the enclosed areas of the boiler houses, gas engine rooms and various gas cleaning and hoisting stations so that these areas require an infallible overpressure protection system. The low pressure condition is even more dangerous. It is at this time that the hazard of an explosive mixture is most likely to occur and steps must be taken to shut off gas to consumers.

*High-Pressure Gas Control*

There is one operating requirement that helps in the control of high pressure in the gas mains. This is the need to remove the quantities of dirt and water, even after the primary washers have done their work, that carry along with the gas in its travel through the mains. Water sprays have been placed in these mains to do this job. Then a special system of drains remove the accumulated water continuously. Each drain is equipped with a seal that provides a hydraulic head greater than the static pressure in the gas mains so that the seals will not blow and release gas into the atmosphere. But each of these hydraulic controlled seals needs protection against an increase in static pressure within the mains that could conceivably overcome their hydraulic head.

Gas bleeders of the burning type, operated by pressure regulators set well below the minimum seal hydraulic head, handle any over-surges in gas pressure. These pressure regulators employ oil as the operating medium. An oil storage tank and two oil pumps are supplied with each installation. The pumps have one electrically driven unit and one steam-driven with the oil pressure developed by the electric pump closing the steam admission valve to the turbine-driven unit. In this way failure of the electric-driven unit for any reason causes the steam unit to operate. At the same time an alarm signal flashes at some convenient operating station.

There are times, however, when pressure surges in the system occur too fast for a bleeder to relieve the pressure before it can build up to a dangerous point. One seal, then, is designed to blow at a pressure point below that of any other seals in the system. It has to be of rela-

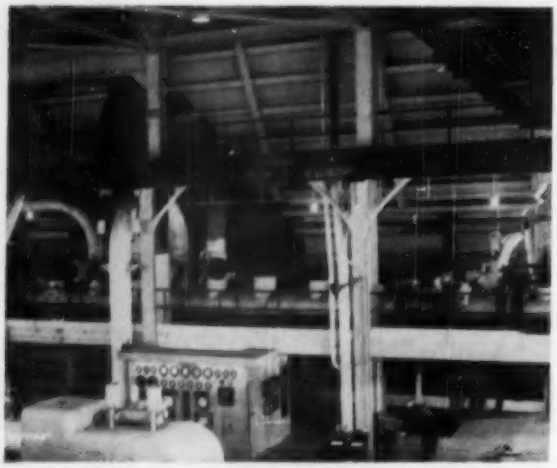

**Fig. 7—Two desuperheating stations, operating in parallel, reduce steam pressure from Pennwood to 275 psi before it is admitted to older low-pressure piping system**

tively large capacity to give quick relief and located in a comparatively open area for safety of personnel. Further it must be supplied with a heavy supply of water so the seal can be re-established quickly. Because of the toxic nature of the gas any seals at points where the gas is pumped into buildings should be the deepest on the system.

*Low-Pressure Gas Regulation*

A combination pressure and safety regulator device serves to safeguard consumers from the explosive mixture hazard of low gas main pressure. It consists of a double diaphragm top connected by a balanced arm. One top controls the line pressure during normal operation and the other assumes control of the regulator element when supply gas pressure drops down to a predetermined minimum.

This class of regulator constantly in operation has little chance to fail in event of an emergency. A standby type of control that goes into service only at the time of a gas supply failure needs frequent and thorough checkups as to its operating ability to work when required.

The low-pressure safety controls offer an excellent means of establishing automatic distribution. By adjusting the pressure at which the controls shut off the gas supply to the various consumer equipment it is possible to eliminate consumers in order of preference as gas supply falls off. Mills and boilers where more than one fuel is available are shut off first.

*Conclusion*

The Pennwood Power Station represents an excellent example of the benefits of a well-integrated power house to a large working steel mill. It affords a means of disposing of byproduct fuels almost as fast as they are formed and in a manner that benefits the industry without creating a problem to its neighbors.

TABLE I—AVERAGE STEAM DISTRIBUTION

| | M. Lbs. per Hour | % of Total |
|---|---|---|
| Generation of electric power | 1190 | 49.0 |
| Blast furnace blowing | 480 | 19.7 |
| Coke oven exhausters | 90 | 3.7 |
| Process and miscellaneous steam | 520 | 21.4 |
| Auxiliaries | 150 | 6.2 |
| Total | 2430 | 100.0 |

## Turbine Blade Temperature Telemeter

A complete instrumentation system for remote indication of gas turbine blade temperatures has recently been designed by M. L. Greenough of the National Bureau of Standards for the Navy Bureau of Ships. The system includes special high-temperature resistance thermometers that withstand large centrifugal forces, an inductive commutator that transmits signal information from the high-speed rotor to external stationary equipment, and electronic circuits that interpret the telemetered signals as temperature measurements. Tests on turbines under actual operating conditions indicate that temperature measurements may be made with the instrumentation system to an accuracy of better than ± 25 degrees F at temperatures up to at least 1400 degrees F, where more conventional methods do not apply.

An essential element for any instrumentation system measuring the temperature of moving turbine parts is a means for taking information from the sensing element in the blades and for transferring it through a coupling mechanism to stationary locations outside the rotating machinery. At low speeds, the slip-ring or commutator and brush arrangements are commonly used. At high speeds, however, or in the presence of oil or water vapor, maintenance of good contact for efficient and reliable signal transfer becomes difficult.

New alternatives to the conventional arrangements are their inductive counterparts, the "inductive slip-ring" and the "inductive commutator". Both have been devised, but the latter has been developed more fully at NBS for inclusion in the instrumentation system. Essentially the inductive commutator consists of a number of pairs of input and output coils on the rotating shaft, with one stationary set of energizing and information-receiving coils mounted on the turbine frame. Rotation of the shaft brings each coil pair into and out of coupling with the stationary coils. Each channel or set of rotating coils is sampled periodically with rotation; thus signal information is sequential in nature. This development offers several useful advantages. Since the inductive commutator is a non-contacting device, there is no wear problem. Large vibration amplitudes have virtually no effect upon the transfer properties. The presence of oil or water vapor also has no appreciable effect upon the signal transfer because the coupling is inductive between low-impedance windings. Moreover, the shaft may be run in either direction without modification of the unit.

# *Bare Tube Walls on Slag-Tap Furnaces*

By **PROF. DR. ING. RICHARD DOLEZAL**

Ostava, Czechoslovakia

**Over the last year or two a series of reports have appeared on the design and operational experience of Czech-built, large-sized high pressure boilers with slag-tap furnaces. This particular one discusses the reasons for choosing certain designs and re-examines them in the light of operational data.**

PRACTICAL experience with slag-tap furnaces in various countries favors a furnace construction employing bare tube walls rather than a refractory-lined one for steam-generation purposes. The advantages are many.

While slag does build up on bare tubes it drops off periodically so that the average heat transfer rate and hence steam generation rate is higher with the bare tube than with refractory-covered installation. In fact with bare tubes very high local heat absorption rates develop which may amount to 500,000 k cal/m$^2$hr. Further, bare tube walls are simpler and cheaper to manufacture, and they eliminate one difference between the slag tap and the dry bottom furnace which is an advantage in size and type standardization.

From the viewpoint of conversion of dry bottom to slag tap furnaces (an acute problem in Europe because of the constant decrease of coal quality) a design calling for bare tube wall construction requires only that the bottom be rebuilt and a slag removal system installed. This assumes, though, that the center to center spacing of the original tube wall is not too great. At the present writing most slag-tap furnaces in Czechoslovakia have refractory-faced tubes. The bare tube wall design is of relatively recent date there.

### *Bare Tube Wall Design*

The earlier slag-tap furnaces of bare tube design employed welded-on fins about 1 in. wide and about $^1/_2$ in. thick. The gaps between fins did not exceed 5 mm. and the vertical spacings ran about 50 mm, Fig. 1. The fins, consisting of flat bars of soft carbon steel, were to protect the furnace lining from the effects of slag. Since they were welded directly to the tubes they increased the heat absorbing surface of the tubes and, in effect, formed a continuous metal wall which prevented formation of a permanent, strongly adhering slag layer on the wall.

The fin width, though, could not be arbitrarily chosen since the fins absorb radiated heat from the flame which in turn raises the fin temperature from its base at the tube to its free end. The average temperature of the fin could not exceed 550 C or the edges of the mild steel fin would burn off. The following formula, $b = 3700 \sqrt{s/q}$, mm gives the maximum permissible fin width, $b$, in mm for a given thickness, $s$, in mm, and a given heat absorption rate for the tube of $q$, in k cal/m$^2$hr. Its application is limited, though, to fins subjected to heat radiation from only one side.

Over and above the restrictions fin size and spacing imposed were the added ones of fabrication difficulties. The welding on of the fins proved to be an expensive process and required subsequent heat treatment particularly if the tubes were made of alloy steel. In addition local piercing of the tubes could occur during the welding process.

Recent practice in large boiler construction has been to employ bare tube walls with the tubes on close center spacing. This construction applies especially where tubes are relatively inexpensive. In such cases if the ratio of $t/d = 1$ (where $t$ = center to center spacing, Fig. 3, and $d$ = tube dia.) fins need not be used, Fig. 2. Such a wall behaves the same as a finned wall as far as slag buildup is concerned.

This situation was found to hold true in rebuilding dry bottom furnaces for slag-tap operation. In some in-

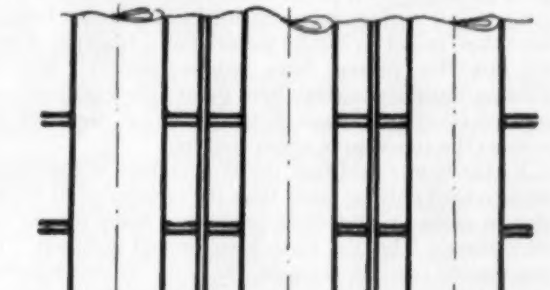

**Fig. 1.—Earlier bare tube, slag-tap furnaces used welded-on fins about 1 in. wide and about $^1/_2$ in. thick with 5-mm gaps between fins.**

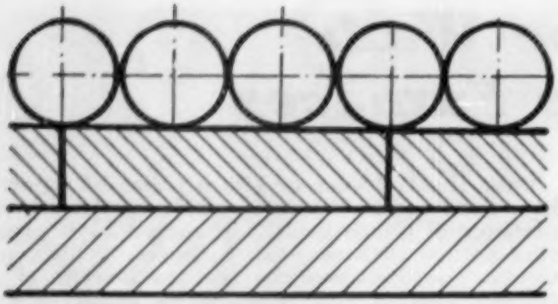

Fig. 2—Recent Czech practice in slag-tap furnace construction employs the bare tubes alone placed on close centers

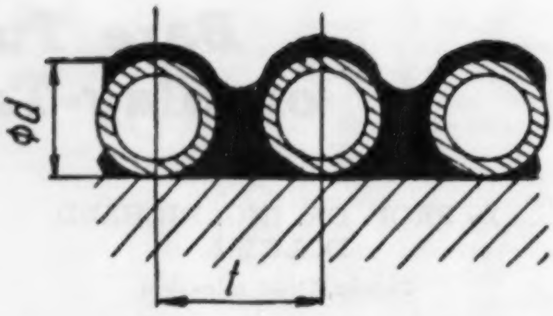


Fig. 3.—Czech boiler wall design establishes a ratio of $t/d$ where $t$ = center to center spacing and $d$ = tube dia.

stances bare tube walls with tube spacings larger than the tube diameter, $t/d>1$, experienced a molten slag action that not only covered the tubes but filled in the inter-tube space, Fig. 3, so the refractory behind the tubings was undamaged. In a specific case (3) where good results were obtained with such a wall the tubes had a 70-mm dia. and a spacing of 110 mm, i.e., a $t/d$ ratio of 1.57. The simple bare tube wall is a considerable advantage over the more complex finned tube design.

While the above example indicates a considerable tolerance for the $t/d$ ratio actually the maximum allowable ratio must be carefully chosen. Otherwise, the lining behind the tubes can melt off if surface temperature gets too high to permit a protective layer of solidified slag to form. This surface temperature for the lining behind the tubes, called $t_w$, can be pictured as a function of the $t/d$ ratio for various flame temperatures, $t_m$, Fig. 4. This part applies to clean bare tubes only because their cooling effect with respect to the lining decreases as soon as the tubes carry a slag coating.

Earlier it was held that the temperature of the lining surface need only be lower than the melting point of the slag to ensure a protective solid layer being formed on its surface. This has since been proved incorrect. In one specific case, for example, the flame temperature ran about 1600 C, the $t/d$ ratio was 1.7 so that the lining surface temperature, according to Fig. 4, would not exceed 1080 C. The melting points of the slag from the coals burned never decreased below 1200 C. Yet melting off of the lining did occur.

The probable cause of this melting off is the formation of a low melting point eutectic of the firebrick with the slag components. According to literary data (4) a eutectic of the components $SiO_2$, $Al_2O_3$, CaO, FeO, typical of the elements in firebrick and slag, may have melting points even below 1000 C.

Another explanation of the above-mentioned phenomena is the formation on the tube surfaces of a thin slag layer which considerably decreased the cooling effect. In this possibility the $t/d$ ratio should preferably be chosen to give a surface temperature, $t_w$, of the lining below 900 C. According to Fig. 4 the $t/d$ ratio for a flame temperature of 1600 C is about equal to 1.4.

### *Heat Stresses in the Tube Walls*

At the instant a slag layer drops off a bare tube wall high heat absorption rates of thermal flow can develop. In special cases this sudden, sharp increase can produce difficulties. Such a special case occurs in natural circulation boilers operating at very high steam pressures (over 150 atmospheres) in which the walls are made of large diameter tubes. Some American plants have installed tubes with wall thicknesses exceeding 10 mm although made of alloy in contrast with the maximum permissible thickness of 7 mm for steam generating tubes in Czechoslovakia and other European states.

Thick walls do not withstand high heat absorption rates very well since the high temperature gradients across the tube walls bring about heat stresses from the different expansion rates of the inner hot and outer less hot surfaces of the tubes. This applies especially to tubes of alloy steel which have lower heat conductivities than mild carbon-steel tubes.

Obviously the presence of a permanent refractory lining and a permanent layer of slag in the tube walls of a slag-tap furnace reduces heat absorption rates and also heat stresses in the individual tubes making up the wall. If the slag layer drops off locally from a bare tube

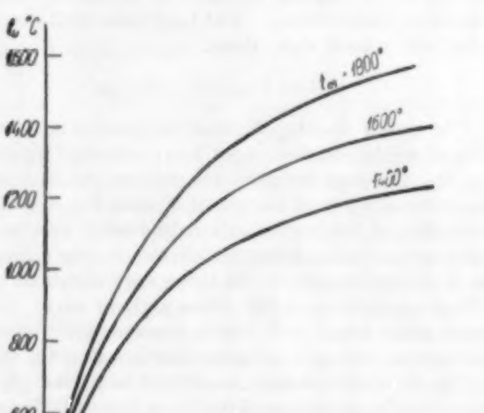


Fig. 4—Graph for determining surface temperature of the refractory behind the tube wall pictures three flame-temperature curves—1800, 1600 and 1400 C—with refractory surface temperatures as the ordinate and the $t/d$ ratio the abscissa.

wall the heat absorption rate increases to several times its value when the slag was on the tube. But this locally increased heat absorption rate does not affect a reduction in flame temperature so the local tube area in a bare tube wall must absorb the entire shock.

It has been found that excessive local heat stresses brought about by alternating heat flow may exceed the yield point of the tube material. Further repeated heat shocks produce a loss of the plastic properties of the metal and failure from heat fatigue. The Twin Branch (2) boiler experience proves this view. There the tubes cracked without preliminary plastic deformation. The reason for the failure was the frequent repeated heat stresses amounting to three times those occurring in refractory-faced tubes.

On the other hand a refractory lining excludes high heat stresses even in thick-walled tubes and dampens the heat shock when the slag layer drops off. A second method of reducing heat shocks is to lessen the thermal blackness of the tube surface. Aluminum, even if oxidized, is less black than oxidized steel tubes. This aluminum coating puts a brake on the heat flow through the tube only until a layer of slag forms on top of it. When this layer forms the tube absorbs radiated heat as well as an ordinary oxidized steel tube. Usually the temperature of a riser tube does not get beyond 400 C so there is no danger of diffusion of aluminum from the surface to the inside of the tube where the perlite in the tube could become graphitized.

Still another method of avoiding tube cracking is to follow the Czechoslovakian and European practice of limiting tube thickness to 7 mm even for boilers of the highest pressure and to tube diameters of 70 mm for all but exceptional cases. This eliminates the danger since

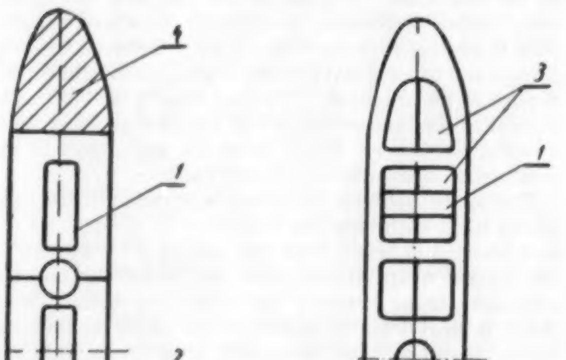


**Fig. 6—Corner burner design, left, above, caused intensive corrosion of tube surfaces, Fig. 5. Rebuilding to design, right, above, corrected the trouble.**

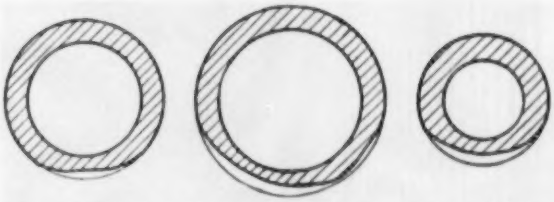

**Fig. 5—External etching action on outer surface of boiler wall tubes, above, occurs in spots directly hit by the flame in certain slag-tap furnaces.**

heat stresses in tubes of these physical dimensions do not approach critical limits.

### *External Corrosion of Tubes*

External corrosion has been evidenced on some furnace tube walls of slag-tap furnaces. It manifests itself as a weakening of the tube produced by an external etching action, Fig. 5. The evidence indicates this form of corrosion occurs only in slag-tap furnaces, but in both bare tube and refractory-faced tube walls, and is confined to spots directly hit by the flame. It is attributed to compounds formed by the combination of the sulfur in the coal with the tube metal. Reid and Cohen (5) thoroughly investigated this form of tube corrosion.

According to the Reid and Cohen findings the atmosphere at the corrosion spots is usually a reducing one. It appears that coarse coal particles tear off the flame when it hits the tube surface. These particles adhere to the tube surface and burn off slowly with an inadequate supply of oxygen.

In some cases introducing a tertiary air supply eliminated the corrosion. But in the first instance it was necessary to limit the hitting of the tube wall by the flame. A finer grinding of the coal to produce a smaller grain size also proved a successful measure. Similarly the position improved if the pyrite was removed from the coal in the mill. In certain cases a protective oxide coating of the affected surfaces solved the problem.

But for the majority of cases the burners had to be reconstructed to eliminate corrosion. Fig. 6 is an example. Here the corner burner design shown on the left caused intensive corrosion. After rebuilding in accordance with Fig. 6, right, the corrosion effects ceased. Apparently a better distribution of the air and pulverized fuel mixture in the furnace explains the improvement produced by the redesigned burner.

### *Czech Operating Experience*

The first large scale Czechoslovakian slag-tap installation using bare tube furnace walls was a 220-ton/hr steam capacity boiler designed to burn any type of Selsian and Ostrava region coal of a calorific value of about 6000 k cal/kg. This boiler is described in some detail in Strojirenstvi, No. 11, 1952 (abridged translation in *Engineers Digest*, February 1954, pp. 65–68). Up to a height of about 6 m from the furnace bottom the walls were of bare tubes with gaps exposing the refractory lining. Above this height the tubes were provided with fins and there was no exposed refractory.

The slag-tap furnace is of rectangular cross-section, 6000 mm by 9000 mm. The burners are corner burners

Fig. 7.—Furnace appearance of combustion space after one month's operation of the first large-scale Czech slag-tap furnace using bare tube walls.

Fig. 8—After several months' operation the lining behind the tubes began to melt away and in 4000 hrs was completely gone.

directed toward the center of the combustion space and inclined against the slag bath. Originally, Fig. 3, the walls were made of bare riser tubes of 70-mm dia. with a center spacing of 120 mm to give a gap of about 50 mm between adjacent tubes. The $t/d$ ratio was 1.7. On the outside the wall was faced with refractory bricks of a thickness of about 60 mm. These bricks, bolted to the tube walls, were covered with a thin layer of asbestos and then another layer roughly 60 mm deep, of slag wool. The entire boiler was encased in sheeting of about 3-mm thickness.

After the boiler went into operation an initial melting and slag outflow was obtained while the tubes were still free of slag layer accumulation. Slag outflow began when the steaming output reached 110 tons/hr, or at about 50 per cent of the boiler's rated output. The coal in use at that time had a slag melting temperature of above 1400 C. The temperatures above the slag pool by optical pyrometer readings measured 1600 C to 1750 C. The slag temperatures decreased steeply in the vertical direction which indicated the very intensive cooling effect of the bare tube walls. At 4 m above the furnace bottom, for example, the flame temperature had dropped to less than 1500 C.

The temperature of the lining behind the tubes was not measured. But according to the graph of Fig. 4 this temperature, $t_w$, should be within the limits of 1080 to 1170 C for flame temperatures, $t_m$, of 1600 to 1700 C and $t/d$ ratio of 1.7.

After a long period in service a continuous, externally smooth-surfaced, 3- to 10-mm thick layer of slag formed on the tube walls. The deeper into this layer of slag the more porous it became, particularly so where it came close to contact with the tube surface. Between the tube surface and the slag layer, though, was a thin, light brown deposit of the finest ash. The slag layer peeled off easily from the tubes and would fall off during startup or shutdown of the boiler. Fig. 7 shows the appearance of the combustion space after one month's service.

The space between the tubes was found to be only partly filled with slag and then only in the part of the wall above 3 m height from the bottom. In the zone of the highest temperatures above the furnace bottom the refractory lining between the tubes was melted away. After several months operation the lining behind the tubes, began to melt away and after about 4000 hrs. operation it was melted through completely, Fig. 8.

The melting point of the slag at no time during this operating run dropped below 1200 C. This melting temperature, incidentally, was determined by use of the Bunte-Baum method and appears on the graph, Fig. 9. These curves apply to granulated or powdered slag after it has flown out of the furnace. The melting point of this slag is lower than that forming on the tube surface because of the concentration and reduction of the higher iron oxides in the slag pool.

During manufacture of the boiler four adjacent tubes in the combustion space were provided with fins 12 mm thick and 23 mm wide leaving a narrow gap of 3 to 5 mm between adjacent fins. These fins stood up very well in operation. The hot edges of the fins and the refractory beneath them remained intact throughout the operating

experience of Figs. 7 and 8. However, the fins welded on the tubes about 4 m above the slag bath were severely burnt at the edges during this time. These fins were 40 mm wide and 12 mm thick. They were fitted on one side only of the tubes so that the edge facing the furnace was roughly even with the front of the tube.

But because the fins record in general was so good it was decided to reconstruct the furnace by welding fins on all the tubes to close the gaps between tubes and thereby obtain an all metallic cooled surface.

After this reconstruction the boiler went back into operation. The flame temperatures above the bottom remain the same as before. The load point at which slag began to flow, namely 110 tons/hr of steaming output, did not change. The tubes again took on a coating of slag up to a height of 3 to 6 m. This solidified slag, smooth, glassy on the outside surface, dropped off easily. Above the 3- to 6-m height the tube walls remained clean. After about 4000 hrs operation the unit was shut down for inspection. There were no evidences of corrosion and tube surfaces were found to be perfect everywhere.

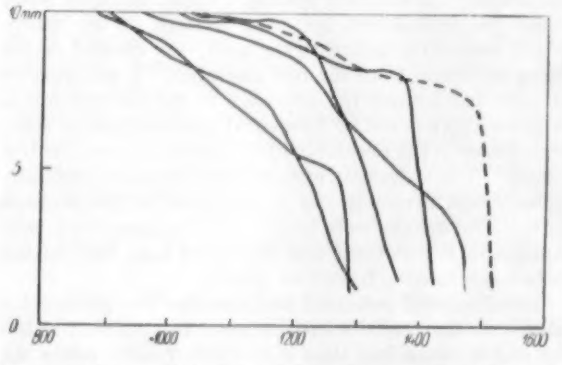


**Fig. 9—Melting point of the slag in the zone, Figs. 7–8, was determined by Bunte-Baum method and is pictured above.**


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## Research to Guarantee the Gas Industry's Future

The 1954 Annual Report of the director of the Institute of Gas Technology, E. S. Pettyjohn, to the associate members and contributors of that organization carried as its theme the need for research to (1) guarantee the future of the natural gas industry (2) avoid the dangers of regulation for price control by furnishing an adequate supply at competitive costs.

The estimated peak production of 12 trillion CF of natural gas will be reached in 1960. This had been projected originally upon a population of 160 million in the U. S. A. by 1960, increasing to 188 million by 1975. But the nation passed the 162.5 million total in July 1954 and the revised estimate indicates 208 million in 1975. The estimated peak natural gas production of 1960, if not exceeded soon, will be entirely inadequate and be getting worse with each succeeding year.

At the moment the industry has no knowledge of what it will cost to produce added increments of gas, nor what price level will be required to meet the needs. The only solution is to further develop methods of making gas from fossil fuels.

The Carthage Hydrocol plant designed to convert natural gas into carbon monoxide and hydrogen and then into liquid fuels, has been an operational and economic failure. For that reason the industry is doubly cautious about any headlong developments.

Synthesis gas, made by pressure gasification of coal in suspension in the pilot unit at the Crawford Station of The Peoples Gas Light and Coke Co., is now being produced at the rate of 500 CF per hr from an initial one CF per hr rate which indicates definite progress in this method. But today, according to Mr. Pettyjohn, a 1000-ton-a-day coal conversion demonstration plant is needed to work out improvements in design and operating procedure and thereby better assess progress.

The gasification of coal is essentially an operation for augmenting the supply of natural gas. The gasification of oil, on the other hand, is primarily one of supplementing the natural gas supply for peak loads in winter in localities where the supply of flowing gas is inadequate and underground storage is not available.

Hydrogen is a major need in hydrogasification, and in the processing of natural gas, natural gas condensates and petroleum products, as well as in the production of ammonia for fertilizers and explosives. One of the best sources of hydrogen is coal.

The Institute has developed a process employing expansion gas turbines for the production of hydrogen from coal. They have a somewhat similar method for hydrogen production from light hydrocarbons. In addition they can use heavy oils in place of coal.

The pressure hydrogasification process offers, in the opinion of the Institute, an opportunity for the small gas plant operator to cut labor and material costs and regain competition advantages for his gas in the market. For the longer range coal or heavy oil can be processed depending upon the relative costs and availabilities of these fuels.

Should the Middle East oil fields develop and Bunker C be dumped on the Eastern seaboard a utility could convert to cyclic pressure hydrogasification to develop a high Btu oil or gas. If coal must be depended upon entirely conversion plants can be set up in the coal fields because every gas transmission line of any size in this country crosses a substantial coal field.

The development of these processes will insure the nation of an adequate supply of gas for the next 150 to 200 years at least.

# ASME Annual Meeting In Review II—

In the earlier report of the recently concluded annual meeting of the ASME carried in the December COMBUSTION the highlights of the meeting were given and most of the papers of direct interest to the power field. There were, however, a number held over for space reasons that are abstracted below.

## Selecting Surface Condensers

In a paper entitled "ApproximateMethods for Selection, Sizing and Pricing of Steam Surface Condensers," **William E. Elligen** of Allis-Chalmers Manufacturing Co. presented in chart form some extremely useful data for preliminary design and estimating of this important component in large steam-electric central stations. The paper includes curves showing the relationship of circulating water requirements and amount of steam condensed to required condenser surface for both one- and two-pass surface condensers. Other curves provide information on weight and cost in relation to surface area and of the cost of tubing in relation to area, including variations for several tube materials. Costs of circulating and condensate pumps are plotted in terms of capacity.

By following the procedure outlined in the paper the designer is able to arrive at an approximate price and weight, taking into consideration changes in circulating-water velocity, initial temperature difference, cleanliness factor and circulating-water temperature.

## Flow in Pipes

In a paper entitled "Turbulent Flow in the Entrance Region of a Pipe," **Donald Ross** reported on work done at the Ordnance Research Laboratory under a Navy contract in connection with the working section flow studies for the 48-in. water tunnel at Pennsylvania State University. A solution of this problem of turbulent flow is of interest to those engaged in the design of tubular heat exchangers and piping systems. The author presents an analytical solution in the form of equations which yield the relative momentum thickness at any station within ten diameters of the entrance, and from this the pressure drop and heat loss are calculated. The ratio of these quantities to the corresponding values for fully developed pipe flow are found to be practically independent of Reynolds number. Comparison of the theoretical expressions with the few data that are available shows good agreement, confirming the formulas for design applications.

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"Effect of a Globe Valve in Approach Piping on Orifice Meter Accuracy" was the title of a paper by **J. W. Murdock, C. J. Faltz** and **C. Gregory, Jr.,** of the U. S. Naval Boiler and Turbine Laboratory at Philadelphia, Penna. There are many situations in power plants in which it is impossible to obtain an adequate length of straight pipe to insure a normally turbulent pattern required for metering fluid flow by means of an orifice. The tests reported in this paper were conducted to show the magnitude of change when less than the minimum straight pipe is used.

The test section consisted of a straight run of 4-in. pipe 147 pipe diameters long, discharging into a condenser, thence to a weighing system. Either steam or water could be introduced into the system. Two sharp-edged thin-plate orifices were used, the control orifice being upstream from the test assembly. A 60-diameter straight run formed the approach to the control orifice. A globe valve could be located at any multiple of three pipe diameters between 6 and 60 upstream from the test orifice. The valve was installed with its stem vertically upward and perpendicular to the plane of the pressure taps. The orifices were constructed in accordance with AGA-ASME standards, and nine pairs were used having beta ratios ranging from 0.30 to 0.85.

The change of indicated flow rate due to a globe valve placed six diameters before an orifice is 2 per cent or less for orifice ratios less than 0.75. For greater ratios the spread of data with or without the valve in the line is of such magnitude that valve disturbance cannot be distinguished from reproducibility. The exact point of no interference is difficult to ascertain. The effect of globe-valve throttling down to 20 per cent relative opening was negligible.

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A useful empirical relationship for the flow of saturated boiler water was presented by **Prof. E. S. Monroe, Jr.,** of Cornell University in a paper entitled "Flow of Saturated Boiler Water through Knife-Edge Orifices in Series." Whenever flashing of liquid into vapor takes place, flow formulas for cold water become erroneous. The author conducted experiments in metastable flow in which the variables studied included (1) orifice size, (2) number of orifices in series, (3) presence of solids in water, (4) spacing of orifices, (5) direction of flow, (6) variations in initial pressure and (7) variations in final pressure. Pressures were measured by calibrated bourdon gages and temperatures by means of mercury thermometers in oil-bath wells.

## Design of Heat Exchangers

**W. C. Beekley** of The Whitlock Manufacturing Co. reviewed the current state of process heat-exchanger practice in a paper entitled "The Economics of Heat-Exchanger Design." Over the past twenty-five years continuing heat-transfer research has resulted in greatly added knowledge and more accurate methods of calculation, while development in the physical characteristics of heat exchangers has made possible increasingly comprehensive specifications governing design and construction. Mr. Beekley urged that there should be a clearer recognition of the economically optimum line between "basic mechanical design" and "design for manufacture." Within limits prescribed by thermal analysis and preliminary mechanical design, design for manufacture should be judged more searchingly by economic considerations. Economies may be effected through quantity

production, by optimum selection of forms of materials, through the increased use of jigs, by maintaining uniform criteria for tolerances and inspection, and by increased attention to what might be termed a standardized approach to the relation of practical construction and ideal conditions.

In a paper entitled "Economic Aspects of Shell-and-Tube Exchanger Design" **William C. Beaton** and **Paul A. Taxter** of the M. W. Kellogg Co. presented a cost analysis of the manufacture of an exchanger of the floating-tube-sheet, removable-bundle-type construction. Material and fabrication costs are compared for major elements using steel varying from medium to high tensile strength. The authors presented curves showing cost variations as a function of diameter with pressure and type of plate material as parameters. Bar graphs were also shown to indicate variable labor and material costs for exchangers of varying pressure and shell diameter.

The problem considered in a paper entitled "Optimum Design of Shell-and-Tube Heat Exchangers" by **M. T. Cichelli** and **M. S. Brinn** of the du Pont Company is how to design for minimum annual cost. The general case is solved where the process fluid rate, process fluid temperature change and the coolant inlet temperature are known and both the tube-side and shell-side pumping costs and heat-transfer resistances are appreciable. Solutions are given for the following cases: (1) fixed coolant rate, (2) fixed shell-side velocity, (3) fixed tube-side velocity and (4) fixed surface area. The method of Lagrange multipliers for optimization calculations is demonstrated and used.

## Flowmeter Development

In a paper entitled "A New Type of Orifice Flowmeter for Compressible Fuids," **F. D. Ezekiel** of the Massachusetts Institute of Technology developed the theoretical basis for a simple pressure-compensated orifice flowmeter that measures the weight flow of a compressible fluid in the presence of a varying upstream pressure. An experimental model tested at pressures ranging between 200 and 1200 psia indicated flow measurements accurate within a six per cent error margin. A method of simultaneously achieving temperature and pressure compensation is also discussed.

**I. O. Miner** of Builders-Providence, Inc., presented a paper entitled "The Dall Flow Tube," which is a primary flowmetering device that has been in use in England for some time. Examination of the Dall flow tube gives the impression that a fluid flowing through it would be subject to a very high head loss. Actually, the author pointed out, the loss is lower than for any other known primary device which operates by developing pressures dependent on the acceleration of the fluid. He added that engineers experienced in the art of flow measurement are even more amazed at the remarkably low pressure drop than are the uninitiated. Limitations are encountered in the measuring of flow of fluids containing solids which might settle out in the throat slot, and more straight pipe is required than for some other standard flow-measuring devices. Also the coefficient becomes variable below a Reynolds number considerably higher than that at which a venturi coefficient starts to vary. Data were provided on coefficients and effects of upstream disturbances for the benefit of researchers and users of Dall flow tubes.

## Bourdon Tubes

Although it is one of the oldest and widest used methods of measuring pressure, the Bourdon tube is still generally designed by cut-and-try methods. The ASME Special Research Committee on Mechanical Pressure Elements contributed two papers as a part of its project to change Bourdon tube designing from an art to a science. One of these papers "Sensitivity and Life Data on Bourdon Tubes," was compiled by **H. L. Mason** of the National Bureau of Standards and the chairman of a subcommittee on empirical data authorized by the ASME Special Research Committee in September 1952. The subcommittee was charged with collecting and analyzing such information on the quantitative performance of Bourdon tubes as could be obtained anonymously from manufacturers and users. This information is presented in tabular and graphic form in the paper. Sensitivities are compared with the theories of Wuest, Wolf and Clark-Gilroy-Reissner. Plots of life data as a function of maximum fiber stress are shown for steel and for phosphor bronze.

In a paper entitled "Theories on Bourdon Tubes" **F. B. Jennings** of the General Electric Co. compares theories of Wuest, Wolf and Clark-Gilroy-Reissner with one that he formulated. Results are presented in curves plotting the same dimensionless ratios in all cases. These curves are useful in designing Bourdon tubes of flat-oval, elliptical or pointed-arc cross-section. Experimental data are compared with a curve based on the author's simplified theory, and an empirical curve of similar shape is drawn. Results of analyses of tip travel and tip force are given.

## Properties of Metals

Three members of the staff of Battelle Memorial Institute, **R. L. Carlson, R. J. MacDonald** and **W. F. Simmons,** presented a paper entitled "Factors Influencing the Notch-Rupture Strength of Heat-Resistant Alloys at Elevated Temperatures." Stress-rupture tests were conducted on notched and unnotched bars of S-816, Inconel "X" Type 550, and Waspaloy alloys at test temperatures ranging from 1200 to 1600 F. The notched specimens had 50 per cent, 60 deg V-notches with root radii ranging from 0.005 to 0.100 in. Results indicated that S-816 alloy was notch strengthened by all of the notches used, in the temperature range from 1350 to 1600 F. Inconel "X" Type 550 was always notch strengthened by all of the notches only at the test temperature of 1600 F. Waspaloy was always notch strengthened by all notches only at the temperature of 1500 F. Factors investigated in the tests included notch geometry, notched and unnotched ductility, modes of deformation and fracture, metallurgical changes and surface conditions. Since the influence of some of these factors can vary from alloy to alloy, it is not feasible to evaluate completely the notch and unnotched stress-rupture be-

havior of a given alloy by any simple method. Instead, the evaluation should be based upon the combined consideration of those factors influential in individual cases.

"The Stress-Rupture Strength of Type 347 Stainless Steel Under Cyclic Temperature" was the title of a paper by **E. E. Baldwin** of the General Electric Co. Stress-rupture tests were conducted in liquid sodium under constant and cyclic temperature conditions. The former were carried out at temperatures between 1000 and 1200 F, while the cyclic test temperatures ranged from 416 to 1294 F with cycle times from 6 to 12 hr. On the basis of the experimental results it was concluded that the mathematical expressions developed by Robinson for calculating the stress-rupture life of steels under cyclic temperature conditions give results which are only an approximation of the expected life. The deviation of the test from the calculated life was attributed to the transient creep conditions which are not considered in the theoretical formulas. The author cautioned against extrapolating the rupture life determined for this particular stainless steel to other conditions.

In a paper entitled "Design Aspects of High-Temperature Fatigue with Particular Reference to Thermal Stress" by **L. F. Coffin, Jr.,** of General Electric Co. a criterion for fatigue failure was proposed. Based on experiments carried out on test specimens subjected both to constrained thermal cycling and constant temperature strain cycling, the criterion relates the number of cycles to failure with the plastic strain change per cycle.

Conventional design practice assumes that the material behaves elastically throughout. The use of plastic strain in a design criterion represents a distinct departure from present design philosophy. The new criterion has the advantage that it is possible to predict the life of a certain machine part for a calculated thermal stress, or conversely, the thermal stress permitted for a certain limiting number of cycles of stress.

## Heat Transfer

Interest in laminar-flow heat transfer in tubes has arisen in the past primarily in connection with heat-exchanger applications involving oils. However, in a paper entitled "Numerical Solutions for Laminar-Flow Heat Transfer in Circular Tubes" **Prof. W. M. Kays,** Stanford University, referred to current interest in high temperature compact heat-exchanger applications where tube diameters are less than $^1/_4$ in. and densities are low. He pointed out that existing solutions for laminar flow heat transfer in a circular tube are generally based on the assumption of a fully established parabolic velocity profile at the point in the tube where heating begins. For high Prandtl number fluids, such as viscous liquids, this idealization does not restrict the usefulness of the solutions, but in the gas range, near a Prandtl number of 1.00, the assumption of a fully established velocity profile at the tube entrance can, for many applications, lead to a considerable error in predicted performance. The velocity profiles of Langhaar have been employed in numerical solutions for boundary conditions of constant wall temperature, constant wall-to-fluid temperature difference and constant heat input per unit of tube length. Local Nusselt numbers have been evaluated for all three cases, and mean Nusselt numbers with respect to tube length have been evaluated for the first two. Experimental data for the cases of constant wall temperature and constant heat input are shown to be in good agreement with the numerical solutions, while differing substantially from solutions based on the parabolic velocity assumption.

There are many instances in heat-transfer devices where an incompressible fluid is heated or cooled while flowing in a channel along a surface which is curved in the direction of flow. In a paper entitled "The Influence of Curvature on Heat Transfer to Incompressible Fluids," **Prof. Frank Kreith** of Lehigh University reported on a study of the effect of curvature by comparing heat-transfer coefficients for fluids flowing along a heating surface of concave curvature in the direction of flow with heat-transfer coefficients for a convex heating surface and for a flat heating surface. Using experiment results of wall shear and velocity distribution obtained by Wattendorf, Nusselt numbers were calculated for Reynolds numbers ranging from $10^4$ to $10^6$ and Prandtl numbers ranging from 0.01 to 100, and for radii of curvature ranging from 0.12 to 1.2 ft. It was found that the heat-transfer coefficient from a heating surface with a concave curvature is considerably higher than for a heating surface of the same curvature in a convex configuration under similar conditions of flow cross-sectional area and flow rate.

# Power Practices in 1954

Power developments over the past year have established new highs in all the reportable areas such as: (1) the highest 12-month (Sept. 1953–Aug. 1954) electric energy production ever recorded by the public utilities—up 6.3 per cent over the same period a year ago to 458 billion kwhrs (2) a combined utility and industrial energy production that reached 5.8 per cent above that of the same 12-month span in 1953 to 530 billion kwhrs (3) a utility and industrial generating capacity that aggregated 114,384,545 kw as of August 31, 1954. All the foregoing are based on the latest available Federal Power Commission reports. This same source further puts installed capacity of utility generating plants at 98,079,729 kw on August 31 as compared to 88,634,002 kw August 31, 1953. Industrial generating capacity had reached 16,304,816 kw as of August 31 as compared to 15,825,091 kw on October 31 of 1953. This industrial capacity includes the stationary plants of electric railroads and railways.

*Capacity Additions*

Manufacture of heavy electric power equipment continues at a high rate according to the Sixteenth Semi-Annual Electric Power Survey of the Edison Electric Institute. This Survey reports a production of new generating units for U. S. electric power systems in 1954 at over 8,600,000 kw delivered during the first nine months and a grand total of about 12,275,000 kw for the full year. As of October 1, 1954, the capacity of new generating units on order and scheduled for shipment amounted to better than 21,000,000 kw.

The E.E.I. Survey further indicated 172 new generating units will supply the expected 12,275,000 kw of new capacity. While this number of new units is the same as that for units placed in service in 1953 the aggregate capacity is about 2,000,000 kw higher. Including the year 1954 the expansion program now scheduled through 1957 calls for placing in service of 456 new generating units with a combined capacity of over 37,000,000 kw.

During the year ending April 30, 1954, the latest available compilation date 29, steam generators of 200,000 lbs per hr capability and larger were purchased for utility installation. This represented an aggregate capability of 20,854,000 lbs per hr or about one-third the amount reported for the year ending April 30, 1953.

Capability of the electric power systems passed the 100,000,000 kw mark some several months ago and it is estimated will reach 104,000,000 kw by the end of 1954, and 129,000,000 kw by the end of 1957.

The peak load for the country as a whole was expected in December and according to estimates would reach to 87,300,000 kw, or 11.2 per cent above the peak load of December 1953. Estimated December peak loads for 1955, 1956 and 1957 are 95,900,000 kw, 102,450,000 kw and 109,100,000 kw, respectively.

Gross margins or capability margins, representing the difference between capability, as listed above, and peak load, are commonly held to be of sufficient magnitude to provide for scheduled maintenance, emergency outages and system operating requirements if practical operating conditions are to be maintained. Insofar as possible scheduled maintenance outages are programmed for off-peak seasons. For the year 1954 and for the country as a whole the estimated gross margin is a predicted 19.3 per cent and will reach 21.5 per cent for 1955. Both these figures are almost identical with those predicted in the E.E.I.'s Fifteenth Semi-Annual Survey of six months ago.

In Region V of the Federal Power Commission supply regions the summer peaks are appreciably higher than the winter peaks which are the traditionally high ones for the country as a whole. Since Region V embraces Louisiana, Texas, New Mexico, Oklahoma, Arkansas and much of Kansas where air conditioning loads largely influence system peaks the shift to a peak in summer months is not unexpected. Several other areas of the country report somewhat similar experiences. Air conditioning loads in the summer months are drastically changing the shape of the annual load curves for a number of utility companies. On many systems in several areas summer peak loads are closely approaching the winter loads.

As a result the E.E.I. believes utility systems may require larger gross margins than previously to assure adequate generating capabilitv at all times.

*Individual System Growths*

The larger utilities in the past year dropped off from their most recently established high rates of new equipment purchases. The average size of unit for the 29 reported sales mentioned above for the period ending April 30, 1954 reflected this decrease with a rating of 719,000 lbs per hr as against 982,000 lbs per hr for the previous year. Five of the 29 units, incidentally, were designed for pressure firing using gas and oil as the fuel. There were no pressure fired units for coal as the initial fuel. Also nineteen of the units were of the reheat type.

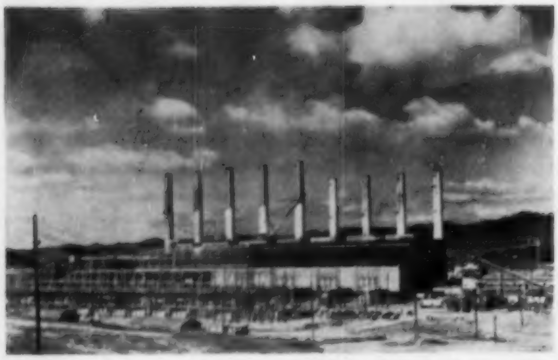
While the above purchases indicate a temporary slow down in rate of growth of electric generating facilities for the industry as a whole the year 1954 for many individual systems saw new equipment go into service that supplied very sizable additions to previous capacity. The American Gas & Electric Co. System, for example, with its late 1954 additions has increased its electric generating capability by more than one million kw within a 17-month span. On the next two pages several representative new power plants for various utility systems are shown.

The Detroit Edison Co. enjoyed the happy coincidence of dedicating its latest power plant, St. Clair, just 75 years from the day Thomas A. Edison perfected the first practical electric light bulb. This dedication held particular significance in this year since 1954 marked Light's Diamond Jubilee Year. This same company recently ordered the world's largest steam generator, a 2,000,000 lbs per hr, 2450 psi, 1050 F unit, and a 300,000 kw turbine generator, also the world's largest, for its River Rouge Plant.

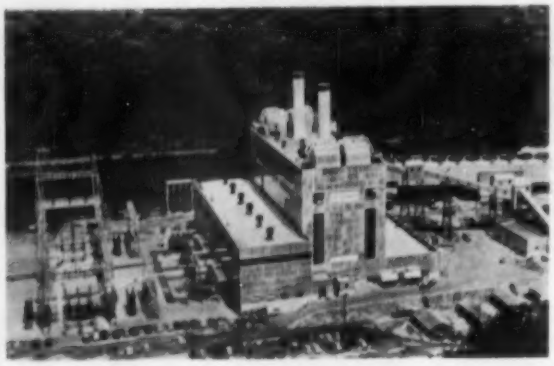
*Atomic Energy Plants*

The plant capacity scheduled for 1955 to supply energy needs for the many Atomic Energy Commission projects represents a most impressive power bloc. The

# Outstanding New

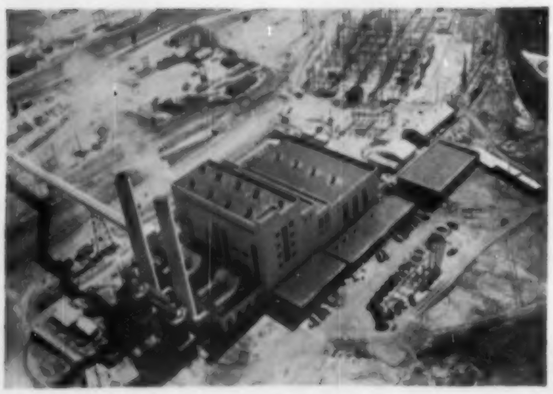


KINGSTON STEAM PLANT of the TVA, when completed, will be the world's largest steam plant with 1,600,000 kw capability. First 150,000 kw unit went into service in February, a duplicate in May, and two others by year's end. 1956 will see plant completion.



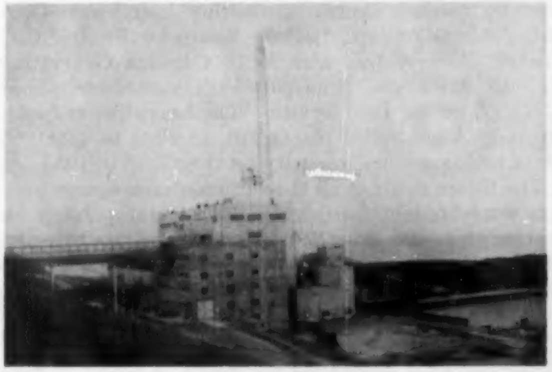
SHAWVILLE STATION of Pennsylvania Electric Co., another addition in the general Public Utilities' expansion program, has two 894,000 lbs per hr, 2080 psi, 1055 F with reheat to 1005 F units in service and two more planned.

SUWANNEE RIVER PLANT, Florida Power Corp., is located on the northern end of the system and will serve the company's wholly owned subsidiary, the Georgia Power & Light Co. as well. The plant is of semi-outdoor design with 33,000 kw capability.



URQUHART STATION of the South Carolina Generating Co., wholly owned subsidiary of the South Carolina Electric & Gas Co., marks the eighth generating station of the system which has a total generating capacity of 536,140 kw.

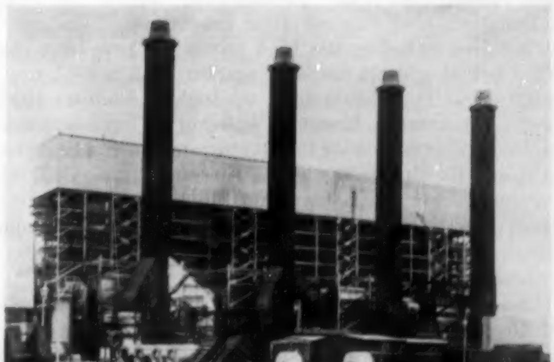
# Plants of 1954



OAK CREEK STATION, Wisconsin Electric Power Co., will eventually have four units each serving 120,000 kw turbine generators of the reheat type, operating at throttle pressures of 1575 psig, 1800 psig, and 2000 psig and throttle temperatures of 1000 F, reheated to 1000 F.

NORTH OMAHA STATION of the Omaha Public Power District was the first modern, reheat-cycle power plant in Nebraska. Its 75,000 kw, 1450 psi, 1000 F turbine generator increased the District's overall capacity by 35 per cent and will contribute 45 per cent of the kwhr requirements.

BARRY STEAM PLANT of the Alabama Power Co. joined the system with two 125,000 kw units during the past year. The plant is designed for ultimate expansion to 1,000,000 kw. Alabama Power Co. now has 890,000 kw of steam-generated capacity and nearly 500,000 kw of hydro.



PITTSBURG PLANT, Pacific Gas & Electric Co., has a generating capacity of 600,000 kw which makes it the largest steam generation station yet built west of the Mississippi. Each of the four boiler units has a steam capacity of 1,080,000 lbs per hr at 2050 psig, 1000 F, TT, and 1000 F reheat.

specially formed electric generating companies—Ohio Valley Electric Corp., Indiana Kentucky Electric Co., Electric Energy, Inc. and South Carolina Generating Co., to name the principals—will contribute about 1,500,000 kw for 1955 service. The heavy power build-up in TVA controlled plants will see close to 2,900,000 kw of additional new capacity on their lines in 1955.

The future needs of all the various atomic energy projects were brought forcibly to the general public's attention by the so-called Dixon-Yates controversy. This particular controversy involved the awarding of a contract to the Mississippi Valley Generating Co., formed by the Middle South Utilities, Inc. and the Southern Co., to supply 600,000 kw to the AEC as against expanding TVA generating capacities to meet this load.

*Nuclear Power*

The AEC announced in the Spring of this year (1) the awarding of a contract to the Duquesne Light Co. for a pressurized water reactor, (2) the development of a five-year reactor program. The Duquesne contract represents the first central station nuclear reactor which upon completion will be capable of delivering 60,000 kw. The other known techniques for nuclear energy developments are covered in the AEC's five-year program. These involve a breeder reactor of intermediate size, an experimental boiling water reactor with an output of 5000 kw, and two homogeneous reactors, one a scale-up of the Oak Ridge experiment as a preliminary to a 65,000 kw unit that will breed uranium 233 in a blanket of thorium and the second a furtherance of the sodium-graphite technology under study by the North American Aviation Co. Late in the year a contract was awarded the American Locomotive Co. for a portable, or packaged, reactor for U. S. Army studies.

The subject of atomic energy in industry was rather thoroughly explored at a meeting sponsored by the National Industrial Conference Board in Mid-October. Based on projected electric industry growth figures one boiler manufacturer, Foster Wheeler Co., predicted 27,000 mw, or one-half the forecast steam capabilities of 54,000 mw, by 1980 will be nuclear fuel-burning units.

*Fuels*

Mine output of bituminous coal for 1954 was estimated by Keystone Coal Manual to approximate 390 million tons, just about the same production as that of 1907 (395 million tons) and considerably below the 450 million tons that marked 1953 production. The electric utilities including the TVA properties have been the single bright spot in the coal market with a 1954 consumption of 115 million tons, up slightly from its 1953 level. Predictions, however, indicate 20 million more tons in 1955 than in 1954 for plant operation and building up stocks for the electric generating industry. Coal requirements for the boilers and stockpiles of the new steam generating facilities of the TVA and the atomic energy project suppliers alone will reach an estimated 11.5 million tons.

The fuel oil industry, according to a year-end report by the American Petroleum Institute, showed a decline in demand for residual oil with 524 million barrels required in 1954 as against 565 million barrels in 1953. Imports of crude oil and refined products, however, continued at about the same rate as established in 1953. Natural gas output, though, moved upward considerably reaching 11 trillion cubic feet or an increase of more, than 368 billion cubic feet over last year.

Certain significant advances have been achieved in the burning of lignite. The recent Minnesota Power & Light Co. experiences in pulverizing high moisture lignite in bowl mill pulverizers and then firing it successfully with standard burners could promote the acceptance of this fuel in those areas where it is readily available.

Industrial plants have been turning more and more to studies leading to the use or reclamation of so-called waste fuels. The spreader stoker has proved a most versatile performer in the problem of handling many of the relatively solid wastes. Chemical recovery boilers in the pulp and paper industry have long-time records in this area and one of 750 ton capacity was recently announced. The refinery industry has developed the CO boiler to successfully solve one of their by-product disposal problems and at the same time reclaim some available heat.

*Equipment Development*

Perhaps the most outstanding impetus to new power plant design has been the decision on the part of two major utilities, the American Gas & Electric Co. and the Philadelphia Electric Co., to invade the supercritical pressure field. The AGE unit scheduled for the Philo power plant will be a 5500-psig, 1150 F unit built by B & W and the Philadelphia Electric selection, for a site at Eddystone, Penna., will be a 6000-psig, 1200 F, C-E Sulzer Monotube design. This latter unit of twin-furnace construction and two stages of reheat is held to be sufficiently large, 275,000 kw, to prove economical and is expected to return net thermal efficiences approaching 40 per cent.

This matter of economics will probably provide the key to future decisions on supercritical installations. The very best plants for subcritical service now operate at an overall thermal efficiency of close to 37 per cent. Modern central stations repeatedly report coal rates as low as three-quarters of a pound per kwhr. The indicated efficiency at Philadelphia Electric's supercritical plant promises a heat rate of near 8400 Btu per kwhr or two-thirds of a pound of coal per kwhr.

The turbine industry is, of course, concerned with this invasion of the supercritical pressure range. Westinghouse Electric Corp. has been awarded the contract for the 275,000-kw, tandem compound, four-cylinder, 3600-rpm turbine generator to go into the Philadelphia Electric Co. installation. During 1954 the world's first close-coupled, cross-compound turbine completed a full year's operating service at the Oak Creek Station of the Wisconsin Electric Power Co.

*Gas Turbines*

There is a growing belief among certain utilities that the gas-turbine generator has features that make it attractive as a base load plant for small and medium sized systems.

Further, many possibilities exist for combining gas turbines with steam turbine cycles to produce improved overall plant heat rates. One manufacturer has developed a number of suggested applications for just such service and the equipment to fit these cycles.

# Engineers Peer into Future at Power Show

A long line of rewly developed equipment, displayed on December 2–7 in Philadelphia, Penna., by the 21st National Exposition of Power and Mechanical Engineering, forcibly demonstrated the accelerated pace at which industry is carrying on. New designs, such as formerly required years to develop, are now being brought into production in months by some of the larger manufacturers.

The exposition was held as heretofore under the auspices of the American Society of Mechanical Engineers, and management of the International Exposition Company of New York, and staged at the Philadelphia Commercial Museum for the first time.

Symbolizing 75 years of progress in engineering, the ASME exhibit at the Power Show featured a steam engine model of 1879 vintage or earlier, in operation alongside the cut-away model of a gas turbine generator rated at 50 horsepower at 40,000 revolutions per minute. This little unit was designed for portable emergency power use.

Things to come in the everyday application of nuclear power were sharply outlined by several related exhibits at the show. Of primary interest were the Atomic Energy Commission's model of the first nuclear power station, and the Westinghouse Electric Corporation's schematic representation of the reactor-turbo-generator system that will feed power from it into the transmission lines of the Duquesne Light Company.

These models were released by the AEC for viewing by a larger audience than ever before saw anything of the kind. The actual development of the first central-station, atomic-power plant has been under way since approval was granted by the Commission. The reactor is being built by Westinghouse, the turbo-generator is being designed and will be installed by Duquesne, which will subsequently purchase the steam output of the reactor.

Of more immediate interest to scientists and engineers was the offering of a basic reator designed for selective application in nuclear research. This unique exhibit is a one-sixth scale model, complete in detail, showing a group of standardized components which can be assembled in various ways to serve stated purposes in nuclear research. The exhibitor is now ready to quote costs on the design and construction of reactors for projects approved by AEC. For the first time, industrial concerns, universities and research institutions will have a catalog from which to select standard parts for reactors to produce neutron and gamma rays, for isotope production, reactor technology, radioactive materials and for biomedical studies.

Advances in combustion engineering were in evidence at the Show and were brought into focus by scale models of new power stations incorporating the latest concepts of design and equipment. One model showed the configuration of the 1954 extension of the Jersey Central Power and Light Company's Raritan River plant. This is the largest steam generating unit in the East utilizing cyclone furnaces. It is rated at 990,000 pounds of steam per hour at 2050 psig and 1050 F. A model of the Mitchell Station of the West Penn Power Company, revealed that that installation is fitted out with no less than 148,000 tons of copper condenser tubes.

### *Package Boiler Units*

The large number of small boiler units at the show testified to the increasing demand for steam and hot water for processing and space heating. Typical "packaged boiler" units are completely self-contained, require neither special foundations nor stacks. They are fully automatic in operation with push-button start and stop, and completely safeguarded. Oil or gas fuel is used and, where heavy oil is to be fired, self-regulating preheaters are furnished.

A remarkable example of compact design coupled with self-regulation carried to the point of automatic starting and stopping, was the automatic "Watchman," developed to save idling costs on a railroad diesel engine. This little package fits a space 18 × 25 ×39 inches, weighs only 250 pounds, and has a rating of 125,000 Btu per hour on 1.25 gph of fuel, with an overall efficiency above 80 per cent. It circulates heated water through the diesel engine jackets at 10 gpm, or thereabouts. The diesels, therefore, are always ready to start without warming up and need not be idled to prevent cooling off during lay-overs. Moreover, when the diesels would ordinarily run cool on light pulls, the "Watchman" cuts in to boost the cylinder wall temperatures and prevent excessive fuel consumption.

### *Internally-Finned Tubes*

A large number of exhibits displayed boiler equipment and supplies, such as insulation, grates and stokers, fire brick and insulation, as well as tubes, gates, gages and all manner of controls. A recent development in water tubes for boilers, also applicable in a variety of heat-transfer units, is the internally-finned tube. This reverses the familiar application of extended radiation from the outside to the inside of the tube. In boilers, it raises the fire-side to water-side ratio from 1.1 to 4.5. "We have known for a long time what it would do," the exhibitor said, "but it also took a long time to find out how to do it." A special process for brazing the longitudinal fins inside the tubing had to be developed before the conception could be brought into production.

One of the leaders in heavy equipment exhibited a self-cleaning condenser which it considers a major contribution to its field. This incorporates a sluice gate arrangement, which reverses the direction of flow, thereby flushing the debris from the inlet box tube sheets and tube ends, saving hours of down time for cleaning the old way. The cleaning operation is now performed without pause in operation.

Public comfort as well as the protection of plant personnel, explains the exhibition of a number of dust-collecting systems. In one, furnace gases are drawn through cones provided with small louvers through which the gases escape, while dust particles are carried through and trapped at the lower end. In others, the cyclone principle is employed in small-sized multiple units in which dust separation is effected by tangential intakes, that set up powerful centrifugal forces. An elaborate system designed to protect heavy dust-forming processes, operates by means of a multiple screening and scrubbing cycle using sprays of water treated with a dust-wetting agent. One of the more elaborate systems employs electric precipitation in the removal of nuisance dusts as from powerhouse waste gases, but more particularly in recovering material of value, such as metallic fumes and dust from nonferrous smelting plants, carbon black from "furnace black" plants, sulfuric and phosphoric acid in chemical plants, and sodium salts in paper mills.

### *Mechanical Vacuum Pumps*

One of the major industrial organizations observed recently that an increasing number of customer equipment specifications were calling for mechanical vacuum pumps, rather than steam air ejectors to remove air and noncondensable gases from surface condensers. Its reaction was to develop a pump for that purpose, one of which was in operation at the show. It is a two-stage unit consisting of two single-stage rotary pumps of the sliding-vane type, with an intercooler mounted in between. The exhibit was remarkable in that it is the first unit of its type designed specifically for the designated purpose.

Automation was reflected at many

of the displays. A large number of indicating and regulating appliances are adapted to remote indication or control, as the case may be, by transmission of pneumatic or hydraulic pressures, or by electric currents or impulses. Groups of such appliances are frequently tied into control centers where conditions at scattered points may be observed at one time and corrections made as required in the interflow of processing events. The observations may be "reported" on separate dials or moving charts; they may be combined into a single graph such as that of the scanner displayed by one exhibitor which may be extended to respond to signals from 20 different points, or 200.

Another step in the treatment of signals from multiple points introduced the digital converter, which another exhibitor displayed. This instrument incorporates a group of elemental units, each of which responds to a signal impulse by moving a printing wheel into a corresponding position. A gang of such units constitutes an elementary recording machine. Associated with clock work and other printing wheels, it records the day and the time. Associated with other suitable gearing, it can add, multiply or store data, feed into a computer, code it on punch cards, or actuate an electric typewriter or a teletype machine for permanent records or distant communication.

### *Variable Speed Drives*

Drives, both speed reducing and variable speed, made up a well-filled classification at the Exposition. There were about a dozen displays of electric motored units and an equal number mechanical. One of the latter offered what appeared to be an entirely new solution of the infinitely-variable friction drive problem. Driving and driven members are opposed beveled disks in contact with which are several relatively large balls, held in touch with the disks by an outer floating ring. Contact pressure is maintained by torque-responsive control of the spacing between the disks. The balls are mounted on axles which are varied in angular relation to the driving axis, so that when parallel with it the speed ratio is 1, but when angled the speed is increased or reduced, according to the tilt of the axle. The exhibitor, a well-known maker of gearing drives, is offering the newly disclosed unit in nine sizes, from $^{1}/_{2}$ to 10-hp input and operating efficiencies of 75-90 per cent.

Another exhibitor has gone in heavily for specific applications of the familiar variable-diameter pulley belt drives.

To meet the requirements of plants where operating conditions are rough, one manufacturer showed a "chemical" motor, especially protected from the

effects of corrosion and also explosion proof. To meet the call for speed variation, a second brought forth an a-c adjustable speed drive consisting of a constant speed squirrel cage motor driving an eddy current clutch with excitation from a permanent magnet generator on the output shaft.

A reliable simple, low-cost, adjustable-speed method of operating d-c motors from a-c lines combines the convenience of alternating current power supply with the excellent starting characteristics and good regulation of direct current shunt and compound-wound motors. One new line incorporating these attributes is offered in 16 models for motor ratings from $^1/_8$ to $1^1/_2$ hp and is available in compact unit construction, or stripped-down designs for use as original equipment by machine manufacturers.

### Detroit Edison Co. Orders World's Largest Equipment

The largest steam turbine-generator in the world, 300,000 kw capacity, was recently ordered for the River Rouge Plant of The Detroit Edison Company from the Allis-Chalmers Mfg. Co. The new unit, a cross-compound design and one of the most economical ever designed and built, will produce a kilowatt hour of electricity for less than three-quarters of a pound of coal. This coal consumption per kilowatt hour is approximately 30 per cent less than the national average. The turbine is designed for an initial pressure of 2400 psig and an exhaust pressure of 1 in. Hg. absolute. Initial temperature is 1050 F. and reheat temperature 1000 F. Both high and intermediate pressure turbines will be on the 3600-rpm shaft. The high-speed generator, which will be rated in excess of 200,000 kva, will have supercharged cooling to both stator and rotor conductors.

Along with this largest steam turbine-generator a new boiler, the world's largest, has also been ordered to supply steam to the turbine. This boiler will supply two million pounds of steam per hour at 2450 psi and at 1050 F.

Foster Wheeler Corporation of New York will build the boiler and its coal pulverizing equipment will be supplied by the Riley Stoker Corporation.

### Personals

**Duncan W. Fraser,** for 14 years chairman or president of American Locomotive Company, passed away at the age of 79. Mr. Fraser, having retired as board chairman early this year, had served 56 years with American Locomotive Company.

Chain Belt Company has announced the promotion of **Bernard Schneider,** who has had almost 30 years of experience in conveyor engineering work, to chief engineer for the conveyor equipment section.

Bailey Meter Company has just established new district offices in Dallas, Texas and Memphis, Tenn. **F. D. Krusemark** will manage the Dallas office and **R. E. Byers** the Memphis office.

The appointment of **William J. Sparling** to the board of directors has been announced by Chain Belt Co. Mr. Sparling will continue in his present capacity as vice president and manager.

**J. E. Summerville,** a field service engineer for Hall Laboratories, Inc., in their Birmingham, Ala., district office has been appointed a member of the headquarters staff in Pittsburgh.

Turbine Equipment Co., New York, has advanced **Harold Sinclair** from president to chairman of the board, and **Donald F. Miller** from executive vice president to president in charge of machinery sales.

**Laurence R. Lee** has been named manager of engineering administration and personnel development in the large steam turbine-generator dept. of the General Electric Co. at Schenectady.

**Harold W. Collins,** general superintendent of the Detroit Edison Co. electrical system since 1945, has been promoted to special assistant to the manager of engineering, **Howard P. Seelye. Delmar D. Chase** moves up from assistant superintendent to the general superintendent of the electrical system. **F. Clifford Pohl** takes over Chase's previous assignment and **Ernest W. Spring,** former staff assistant replaces Pohl.

**Edmund B. Besselievre,** formerly chief sanitary engineer of the international division of the Dorr Co., has assumed the post of manager for the newly formed industrial wastes division of Kaighin & Hughes, Inc., piping and mechanical contractors.

The election of **Dr. Jacob B. Taylor,** vice president, business manager and treasurer of Ohio State University, to the board off directors of the American Gas and Electric Co. raises the board membership to 12.

**Robert C. Williams,** new comptroller of the National Valve and Manufacturing Co., was previously assistant secretary-treasurer of Henry F. Teichmann, Inc.

**Dr. Wayne E. Kuhn,** is general manager of the Texas Co.'s research and technical department and will have **W. A. McMillan,** as his assistant general manager and **Gus Kaufman,** as manager of operations.

**F. Loomis Lamprey** has been named manager of mechanical engineering for the construction engineering section of General Electric Co.

**John A. Steer** has been appointed sales manager of the boiler trim division of Yarnall-Waring Co. from his former post of sales manager for the Philadelphia and New York districts.

**James L. Head,** mining engineer with Anaconda Copper Mining Co., was re-elected as president of the United Engineering Trustees, Inc., at their fifty-first annual meeting.

**Norman Lieblich,** general sales manager, was raised to the post of vice president of Kieley & Mueller, Inc.

**Harry Engvall,** formerly chief engineer of the turbine and gear departments of DeLaval Steam Turbine Co., has been promoted to the post of

executive engineer. His former duties will be handled by John S. Haverstick.

**Joseph R. Denton,** formerly with Worthington Corp., has been appointed manager of Cochrane Corp.'s newly formed New York district sales office.

The Perfex Corp., has advanced **Irving G. Bohrman** from vice president and general manager of the Radiator Division to president of the board and **Ernest H. Panthofer** from assistant general manager of the Radiator Div. to the position of vice president of the board.

**H. D. Emmert,** engineer-in-charge of development for Allis-Chalmers Mfg. Co.'s steam turbine section, was appointed assistant chief engineer.

**John M. Birkenstock,** general manager and director of The Green Fuel Economizer Co., Inc., has retired after 30 years' association.

**Jefferson C. Falkner,** formerly manager of electric production for Consolidated Edison Co. of New York, has joined Copes-Vulcan Division, Continental Foundry & Machine Co. as an engineering and customer consultant in the development of steam power plant equipment.

**Kenneth A. Roe,** engineer of Burns & Roe, Inc., has advanced to executive vice president.

Green Fuel Economizer Co., Inc., has announced the appointment of **Kenneth B. Gair** to vice president and general manager.

Appointment of **Gustav Schwab, Jr.,** as manager of its Marietta, Ohio, pipe fabrication plant, has been announced by the Machinery Div. of Dravo Corp.

**William J. Fadden, Jr.,** who for a number of years has been in charge of major projects, has been named chief mechanical engineer of The Kuljian Corp.

Le Roi Div. of Westinghouse Air Brake Co. in Milwaukee has advanced **Don S. Permar** from sales manager of stationary air compressors to the newly created post of field sales manager.

**Tibor F. Nagey** heads the newly formed nuclear division of Martin Aircraft of Baltimore. Key managers in the new division are: **Dr. Robert Spooner,** nuclear research and development, **James Dunlop,** nuclear manufacturing, **William A. Maxwell,** nuclear production engineering, **Howard F. Dunlap,** nuclear products development and **Russell L. Hopping,** marketing research.

**Allison C. Neff,** vice president of Armco Drainage & Metal Products, Inc., has been nominated as candidate for president of the National Society of Professional Engineers.

**Harry A. Winne,** retired vice president of General Electric Co., has been awarded the 1954 John Fritz medal by the Founding Engineering Societies.

**Daniel H. Dykins** has been appointed manager of utilities of The Kuljian Corp.

Executive vice president **Henry V. Erben** has been appointed group executive in charge of the new distribution group of General Electric Co. with executive vice president **Robert Paxton** succeeding Mr. Erben as group executive in charge of the apparatus group.

For notable scientific achievement in the field of solid fuels, **John F. Barkley,** fuels technologist in the office of the chief, fuels and explosives division, Bureau of Mines, was presented the Percy Nicholls Award in Pittsburgh on October 28, 1954. Mr. Barkley has served 35 years with the Bureau of Mines and is credited with saving the Government millions of dollars in the purchase of coal and in the selection of efficient fuel-burning equipment for Federal establishments.

## Business Notes

Jervis C. Webb, pres. & general mgr., Jervis B. Webb Co., Detroit, Mich., was elected president of the **Conveyor Equipment Manufacturers Association** at its 21st annual meeting. R. C. Sallenberger was re-elected executive vice president and will be chief staff executive in the association's Washington, D. C., headquarters. Fred S. Wells was elected vice president, E. E. Boberg, treasurer and R. B. Mass, secretary.

**Enterprise Heat and Power Company** of Chicago has announced that they will serve as the executive Midwest factory branch for the Heat-Timer system of heat regulation. This was made after $1^1/_2$ years of testing the system in the Chicago area.

Secretary of Interior Douglas McKay announced the five **Bureau of Mines Regions** that will replace the present nine upon completion of the current Bureau reorganization. The five new regions will be in Albany, Oreg., San Francisco, Calif., Denver, Colo., Bartlesville, Okla., and Pittsburgh, Pa. Under the reorganization all bureau operations in a region, except for those dealing with health, safety, coal-mine inspection, and helium, will be directed from regional headquarters.

At a special meeting of the Board of Directors of **Penn Industrial Instru-**

ment Corp. the board voted to accept a proposed plan for merger of that company with **Burgess-Manning Co.** The board of directors of Burgess-Manning Co. previously approved the merger. This is subject to shareholders of both companies approval and to that of various legal details by the legal counsel.

By a surprisingly heavy total vote a majority of eligible voting members of **The American Society of Heating and Ventilating Engineers** expressed their approval of changing the name of the sixty-year old engineering society to **American Society of Heating and Air-Conditioning Engineers, Inc.** The new name has been filed with the secretary of state of the State of New York and became effective November 23, 1954.

M. A. Ellsworth, vice president and director of sales for the **Fluor Corp., Ltd.,** announced the opening of a Denver, Colo., district sales office. Under the management of L. O. Calkins, district sales manager, the Denver office will serve the states of Colorado, Utah, Montana, Wyoming, and New Mexico plus Southeast Idaho and the country of El Paso, Texas.

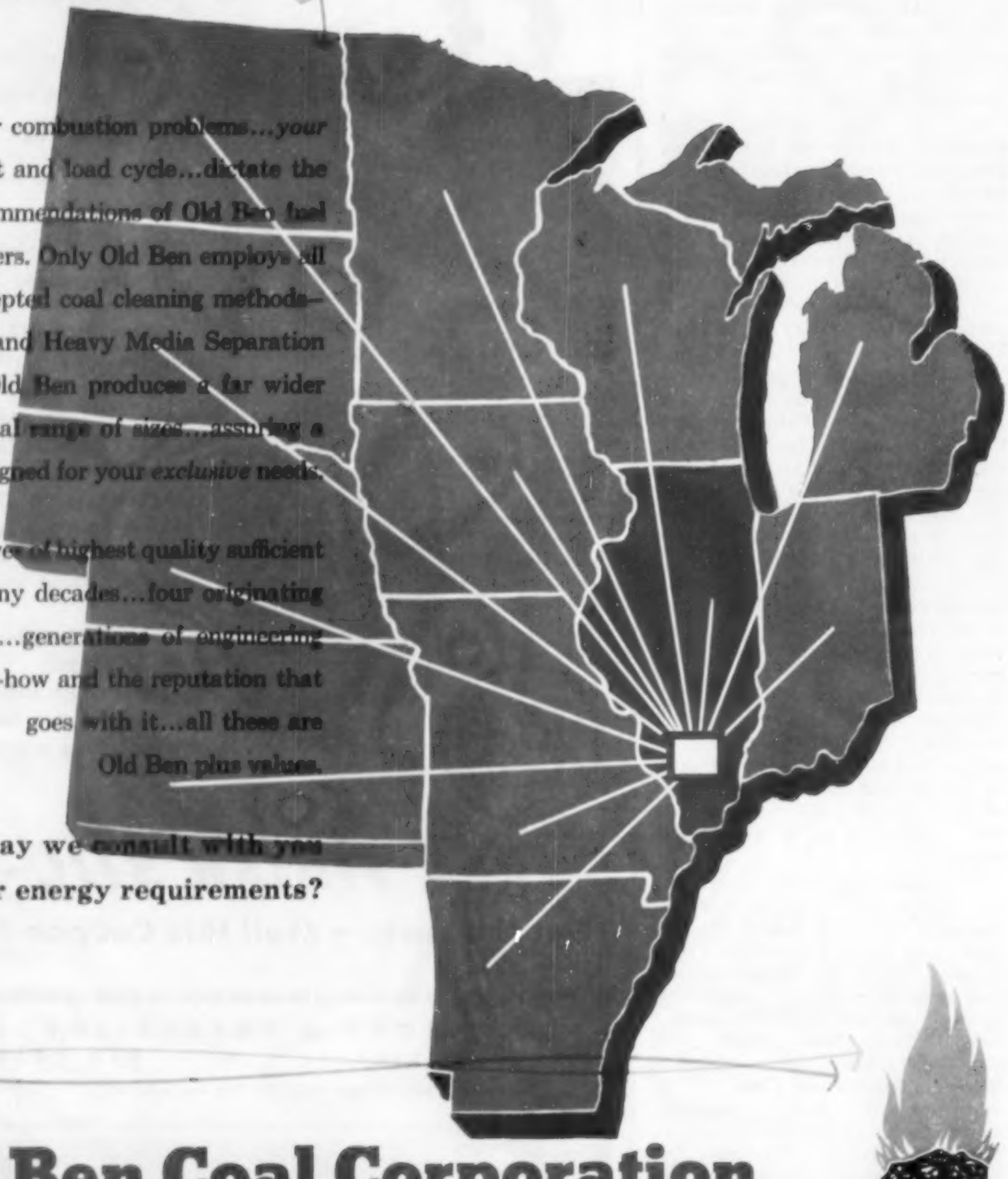
Under the terms of an agreement with a substantial majority of the shareholders in the **Griscom-Russell Co.,** the **General Precision Equipment Co.** will exchange a portion of their stock for stock in Griscom-Russell. The agreement, if consummated will result in a transfer of control to General Precision Equipment.

The coal unloader of the **Jersey Central Power and Light Co.,** Raritan River Plant, is the first unloading tower or bridge in the world to use magnetic amplifiers and the first to use the new **Westinghouse Electric Corp.** high-speed (3600 rpm) *Rototrol* speed regulators. The unloader operates on a 33-second cycle to handle 600 tons of coal per hour. Bucket operation is managed by two 155-hp d-c motors and a 44-hp d-c motor operates the trolley.

The newest and largest steam electric power generating unit of the **Southern California Edison Co.,** including the largest boiler of its type in service west of the Mississippi, has just recently gone into commercial operation at its Redondo Steam Station, Redondo Beach, Calif. Designed and constructed by **Stone & Webster Engineering Corp.** in collaboration with Edison Co. engineers, this unit adds 160,000 kw capacity to the Edison system. This brings the combined Redondo Steam Station to 448,000 kw capacity and the total of Edison steam plants to 1,144,500 kw. (For other developments see pp. 49–52).

# Are YOU on this MAP?

***In these 12 states OLD BEN COAL provides LOW COST STEAM! ...NOT just a low price at destination!***



*Your* combustion problems...*your* equipment and load cycle...dictate the recommendations of Old Ben fuel engineers. Only Old Ben employs all three accepted coal cleaning methods—Air, Water and Heavy Media Separation—and Old Ben produces *a far* wider than usual range of sizes...assuring a product designed for your *exclusive* needs.

Coal reserves of highest quality sufficient for many decades...four originating railroads...generations of engineering know-how and the reputation that goes with it...all these are Old Ben plus values.

**May we consult with you on your energy requirements?**

# Old Ben Coal Corporation

**Chicago 4, Illinois**

# What it Takes to Pipe the Atom

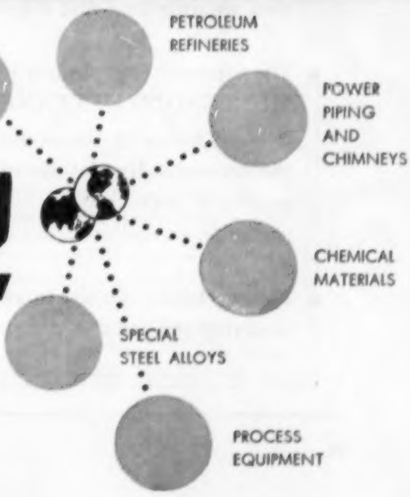
No power piping or chemical process piping job is too large or complex for The M. W. Kellogg Company. At the AEC's billion-dollar gaseous diffusion plant, Paducah, Kentucky, it entails the installation of 3,450,000 feet of tubing and pipe for the main process, auxiliary, and instrument piping, and represents 17,500,000 total man-hours—850,000 engineering, 2,600,000 welding. M. W. Kellogg also will test the system prior to use.

M. W. Kellogg's responsibility started long before a single length of pipe could be put in place. It included an on-the-site welding school—to help all contractors master unfamiliar techniques, and a temporary pipe fabricating and fitting shop costing one million dollars. Once work was started, the control system to prevent product contamination was so strict that not even a thumbprint was allowed on the interior of the pipe.

The size and complexity of the Paducah assignment . . . the outstanding labor relations and safety records achieved . . . help explain why The M. W. Kellogg Company is pre-eminent in the engineering and construction of jobs ranging from public utility piping systems to complete refineries and chemical processing plants.

# M.W. Kellogg

**ENGINEERING FOR TOMORROW**

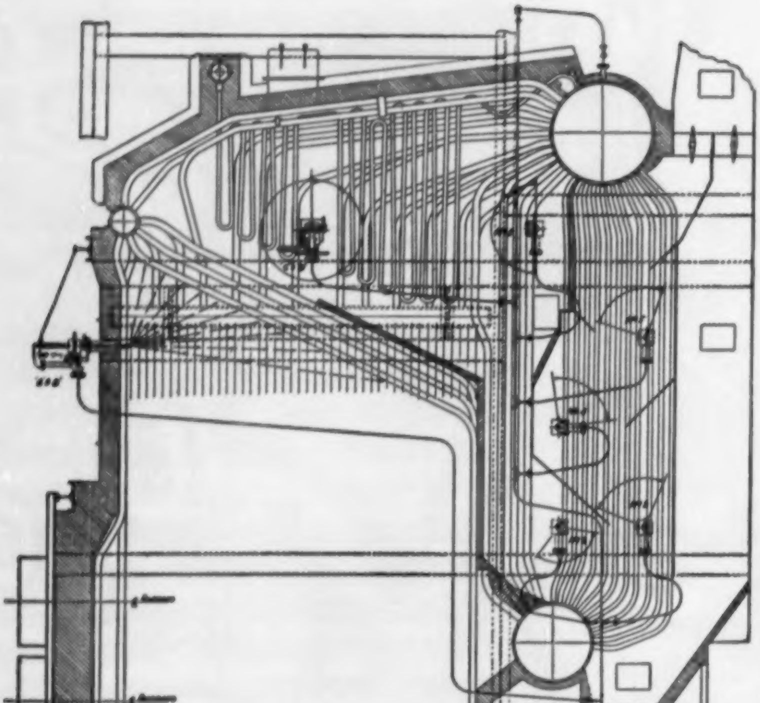



THE M. W. KELLOGG COMPANY, NEW YORK 7, N. Y.

The Canadian Kellogg Company, Limited, Toronto • Kellogg International Corporation, London.

SUBSIDIARIES OF PULLMAN INCORPORATED

# CLEAN HEATING SURFACE and LOW MAINTENANCE



***460 p.s.i. PULVERIZED COAL FIRED BENT TUBE BOILER***

- The high temperature zone, first pass screen tubes are cleaned by BAYER RETRACTABLE GUN TYPE MASS-FLOW CLEANERS located in the front furnace wall. When not in use the nozzle is retracted from the furnace, where it is away from the heat, thus assuring long and efficient service life.

- The superheater is cleaned by BAYER LONG RETRACTABLE MULTI-NOZZLE CLEANERS. The elements are advanced for cleaning and after the cleaning cycle are entirely withdrawn from the furnace. By the use of such Retractable Cleaners heating surface is kept clean at all times, and element maintenance is negligible.

- The rear banks of boiler tubes are cleaned by BAYER conventional revolving elements.

The soot cleaner system illustrated emphasizes the fact that the soot blower in every case should be engineered to suit the operating conditions of the boiler to which it is applied.

BAYER engineering is at your service at any time. We will gladly cooperate with you in order that the best equipment may be correctly applied to efficient cleaning of heating surface under the operating conditions in your plant.

Over the years a large Mid-West Utility Company has used BAYER SOOT BLOWERS. The first installation was made over twenty years ago. Eleven repeat orders for BAYER SOOT BLOWERS to equip new boiler installations have been ordered. The boiler illustrated at the left was installed last year. The record of efficiency, dependability and service demonstrated by BAYER EQUIPMENT in past years resulted in BAYER being selected for the new boiler.

## The Bayer Company

ST. LOUIS, MISSOURI, U.S.A.

FOR HIGHEST FIRST AND FINAL VALUE BUY BAYER

# ARE CLOGGED LINES LIKE THESE CUTTING YOUR WATER SUPPLY?

## *Over 1½ Miles of Buried Water Line Chemically Cleaned IN PLACE by Dowell Service*

You don't have to dig up water lines in order to clean them! Take the case of a major railroad that had over 8600 feet of *buried* water lines, ranging from 2 to 12 inches in diameter. The capacity of these lines had been greatly reduced by scale deposits. Dowell Service used liquid solvents to clean all the lines, *in place*, during a period of only six days with a minimum interruption in service.

Dowell Service offers *fast*, effective chemical cleaning of pipelines of all kinds—water lines, disposal lines and product lines. And, whether these lines are underground or above, indoors or out, no digging or dismantling is necessary. Dowell solvents are designed to dissolve the accumulated deposits, and are introduced through regular connections. Because they are liquid, Dowell solvents reach wherever steam or water can flow, cleaning places inaccessible by other methods—angles, curves, valves, complicated surfaces and hook-ups. *Experienced* Dowell engineers do the job using Dowell-designed truck-mounted pumps, mixers and control equipment.

Many other types of equipment can also be cleaned chemically by Dowell. If you have boilers, condensers, evaporators, bubble towers, water wells or other operating equipment where deposits are reducing capacity, let Dowell Service *save you time and money in maintenance cleaning!*

FIND OUT ABOUT CHEMICAL CLEANING! There are many places in your plant where Dowell Service can clean equipment faster and better than out-dated mechanical methods. Call your nearest Dowell office for a fact-filled book. Or write direct to Tulsa, Dept. A-25.

# *DOWELL SERVICE*

***Over 100 Offices to Serve You with Chemical Cleaning for:***

Boilers • Condensers • Heat Exchangers • Cooling Systems
Pipe Lines • Piping Systems • Gas Washers • Process Towers
Process Equipment • Evaporators • Filter Beds • Tanks

***Chemical Services for Oil, Gas and Water Wells***

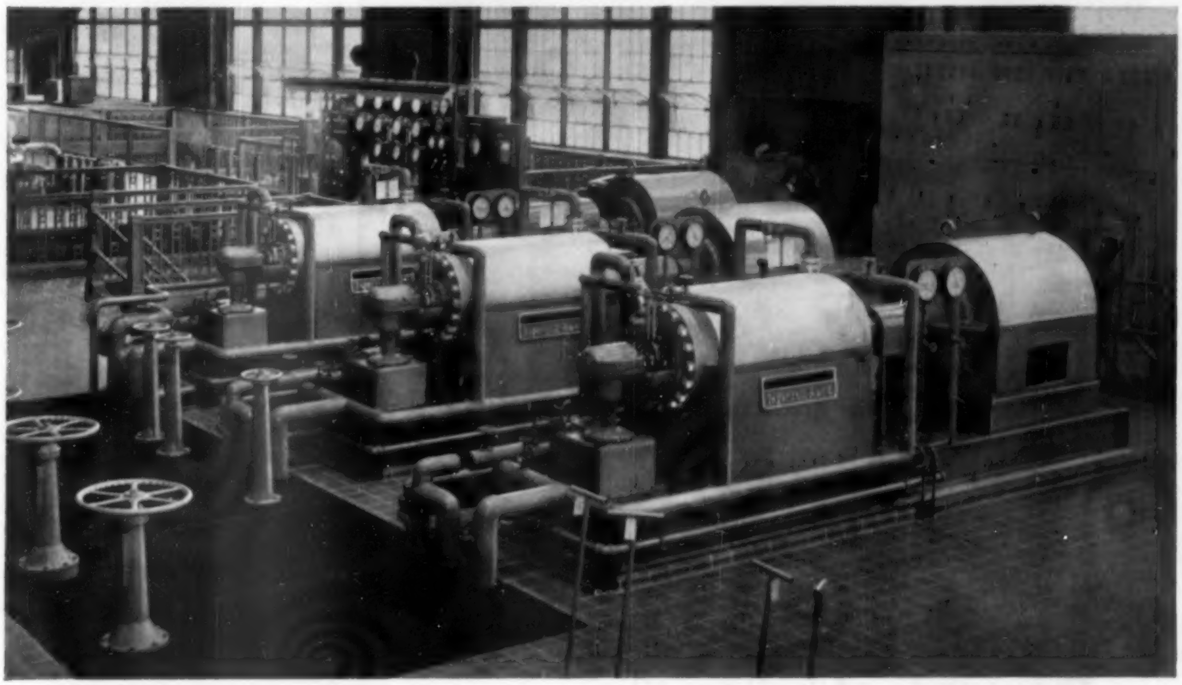
**DOWELL INCORPORATED**
**Tulsa 1, Oklahoma**

**DOWELL**

*A Service Subsidiary of*
THE DOW CHEMICAL COMPANY

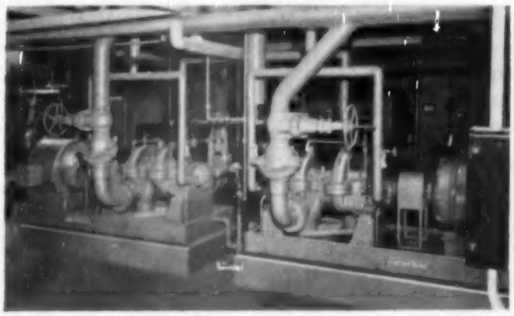
# STANTON STATION of THE SCRANTON ELECTRIC CO.

## served by Ingersoll-Rand boiler feed pumps of proven dependability and high efficiency



## *Three 475 gpm, 1735 psig 10-stage Class CHTA units chosen for 40,000 kw Unit No. 3 . . . .*

Ingersoll-Rand "double-case" boiler feed pumps have stamina and endurance to meet the needs of The Scranton Electric Company and many other utilities throughout the nation.



Also installed at Stanton Station: two Ingersoll-Rand Class 4GT two-stage horizontally-split centrifugals in ash sluice service. Gilbert Associates, Inc. were consulting engineers for the installation of Unit No. 3.

A vertically-split inner assembly is enclosed in a heavy forged steel outer housing. As a result of this sturdy cylindrical "double-case" construction—and other I-R features such as leak-proof metal-to-metal joints, stainless steel fits, and thrust-free running balance—these pumps have an unusual record of long-trouble-free service in high pressure installations. Maintenance has been simplified—and reduced to a minimum.

See your nearest I-R representative for further information on Ingersoll-Rand pumps and other power plant equipment of proven dependability.

**Ingersoll-Rand**

Cameron Pump Division

11 Broadway, New York 4, N. Y.

10-12

PUMPS • CONDENSERS • COMPRESSORS • AIR & ELECTRIC TOOLS • ROCK DRILLS

## Advertisers' Index



*(Continued on page 69)*

# Fly Ash Problem Solved By Central Station

This Pennsylvania utility felt that as long as you can *see* dirty stack discharge, you have a problem. To solve it, they decided to insist on fly ash collection equipment with very high efficiency.

The electrical precipitators they chose, which were placed after existing mechanical collectors, are Cottrells, designed and built by Research-Cottrell. Their effectiveness is demonstrated in the above unretouched photographs. At the left, the precipitators were turned off long enough to take the picture showing the volume of fly ash discharged by the boilers. At the right, the precipitators are turned back on. Stack discharge is visually clean.

This is another example of industry's trend toward establishing its own higher standards for nuisance abatement. Research-Cottrell, which has made more fly ash installations than any other company, cites the following comparison:

In the period from 1923 to 1939 only 11% of its power plant customers specified fly ash collection efficiency of 95 to 98%. In recent years, that 11% has risen to fully 90%.

One reason, of course, is the generally increasing emphasis on community relations. Another factor is that farsighted companies are anticipating stricter smoke regulations. They are anxious to install equipment that will end their smoke problems now and also prevent such problems from occurring in the future.

Still another factor is this. In recent years, with modern coal pulverization and advanced boiler design, there has been an increase in the fineness of fly ash particles. This calls for the most efficient equipment available.

Read—in Bulletins FA and MI—about Cottrell equipment and the Research-Cottrell's MI Rapper. This device eliminates rapping puffs and enables the precipitator to maintain, continuously, its high collection efficiency. Write for your copies today.

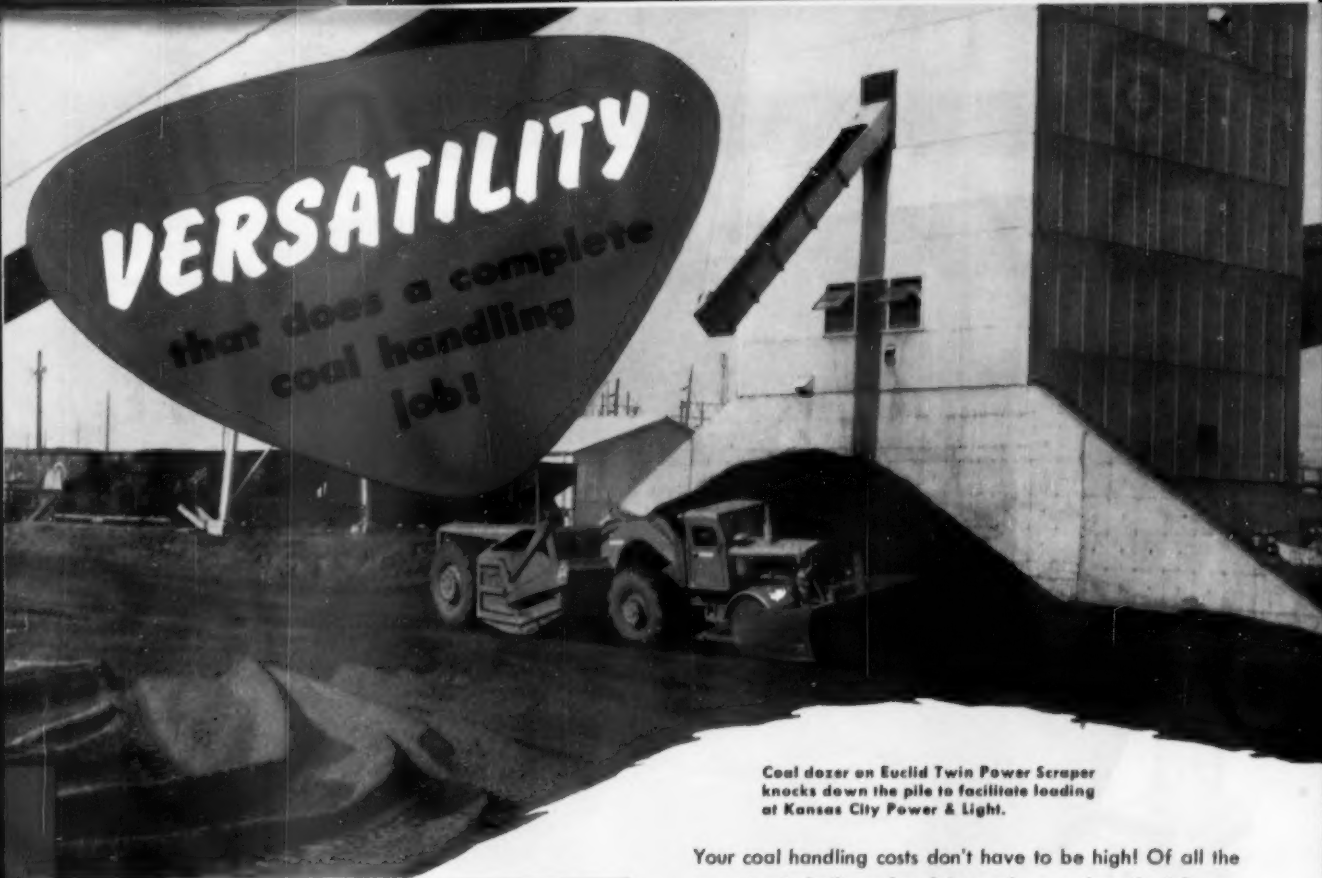
RC-193

**RESEARCH-COTTRELL, INC.**

A WHOLLY OWNED SUBSIDIARY OF RESEARCH CORPORATION

*Main Office and Plant: Bound Brook, N. J.*
*405 Lexington Ave., New York 17, N. Y. • Grant Building, Pittsburgh 19, Pa.*
*228 N. La Salle St., Chicago 1, Ill. • 111 Sutter St., San Francisco 4, Cal.*

# VERSATILITY that does a complete coal handling job!



Coal dozer on Euclid Twin Power Scraper knocks down the pile to facilitate loading at Kansas City Power & Light.

"Twin" Scraper dumps its big load . . . spreads . . . and compacts on the fly!

The "Euc" maintains a well-drained, compacted pile . . . self loads for storage or haul to the plant.

Your coal handling costs don't have to be high! Of all the ways to stockpile and reclaim coal, none does the job as efficiently and completely as the Euclid Twin-Power Scraper.

The "Twin" is completely self-loading in loose, compacted, wet or frozen coal. It builds, raises or extends a well drained and compacted stockpile . . . carries big loads at speeds up to 30 m.p.h. Using Euclid Twin-Power Scrapers for coal handling is more economical and a great deal more flexible than permanent cranes and conveyors — from both original investment and operating standpoints. The "Twin" method costs less per ton handled — as compared to other equipment — because of the speed, capacity and versatility of these "Eucs".

Kansas City Power & Light Co. uses a Euclid "Twin" at its big Hawthorn station and is well satisfied with the high production and low maintenance obtained. Installation of a coal dozer further increases the scraper's versatility by enabling the "Euc" to dress edges of the stockpile, knock down loose, steep piles at the delivery area, and clean up at the dumping hoppers.

Many other industrial plants and public utilities are cutting their coal handling costs with Euclid Twin-Power Scrapers. There's a good chance your Euclid Distributor can show you the way to lower costs, too!

**EUCLID DIVISION** GENERAL MOTORS CORPORATION, Cleveland 17, Ohio

EUCLID THE PIONEER

# Euclid Equipment

FOR MOVING EARTH, ROCK, COAL AND ORE

GM GENERAL MOTORS

# Shaw's 8 point production story is your piping fabrication success story

**Whatever your piping fabrication and installation problem—processing plant, power plant, steel mill, refinery, or industrial plant—Shaw employs this vital 8-point production method to assure you a job well-done from inception to completion, at lowest cost to you.**


**1** Competent Shaw engineers plan efficient, economical procedures for your piping project from inception to performance-ready installation


**2** Shaw gives you all the fabricating services necessary for dependable, quality piping that conforms exactly to the specifications for your project


**3** Shaw has no corner on brains, but each man on the company's team of specialists is trained for the phase of piping fabrication he performs


**4** Behind the trained and tireless eyes of Shaw technicians is your assurance of quality finishing in the fabrication of your piping project


**5** You spend your piping dollar for all it's worth when you buy from Shaw, where your requirements are accurately translated into minute details

**6** Every piece of Shaw fabricated piping bears the Union label—your assurance that your job has been produced by experienced journeymen


**7** There's more to a bid than price, and you avoid the low, gimmick-type bid when you count on Shaw for careful, accurate bidding on your job


**8** "Look ahead!" is the byword of every phase of Shaw production—modern facilities, latest production-line techniques, time-saving equipment

**Whether your piping project is large or small, you buy dependable, quality fabrication and installation when you place your contract with Shaw. Buy from Shaw—it costs no more and pays all ways.**

BENJAMIN F.
SHAW
COMPANY
Wilmington, Delaware